

**Economic Analysis Framework for Freight Transportation Based on Florida
Statewide Multi-Modal Freight Model**

Final Report



By

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DISCLAIMER

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

UNITS CONVERSION

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
AREA				
in²	squareinches	645.2	square millimeters	mm ²
ft²	squarefeet	0.093	square meters	m ²
yd²	square yard	0.836	square meters	m ²
ac	acres	0.405	hectares	ha
mi²	square miles	2.59	square kilometers	km ²

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
VOLUME				
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft³	cubic feet	0.028	cubic meters	m ³
yd³	cubic yards	0.765	cubic meters	m ³

NOTE: volumes greater than 1000 L shall be shown in m³

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
MASS				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
TEMPERATURE (exact degrees)				
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
ILLUMINATION				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m ²	cd/m ²

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
AREA				
mm²	square millimeters	0.0016	square inches	in ²
m²	square meters	10.764	square feet	ft ²
m²	square meters	1.195	square yards	yd ²
ha	hectares	2.47	acres	ac
km²	square kilometers	0.386	square miles	mi ²

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m³	cubic meters	35.314	cubic feet	ft ³
m³	cubic meters	1.307	cubic yards	yd ³

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
TEMPERATURE (exact degrees)				
°C	Celsius	1.8C+32	Fahrenheit	°F

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
ILLUMINATION				
lx	lux	0.0929	foot-candles	fc
cd/m²	candela/m ²	0.2919	foot-Lamberts	fl

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
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16. Abstract <p>Freight transportation plays a vital role in local and regional economy. The markets and businesses from different regions and locations can be connected through freight movements. But it is difficult to quantify the economic contribution of freight transportation. To date, no such study in Florida has been conducted. One of the major functions of the freight transportation system is to ship goods and materials to meet the needs of individuals and businesses. Today, Florida transports a large number of products locally and to other states as well as abroad. Florida's rapid economic growth over the past few decades has resulted in rising freight demand. Therefore, it is important to quantify the real economic impact of freight transportation in Florida.</p> <p>In this research, an economic impact framework based on the Florida FreightSIM was developed. A Python software based on the economic analysis framework which is called Florida Freight Economic Impact Kit was also developed. The project concluded with analysis of two case studies.</p>			
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EXECUTIVE SUMMARY

Background statement

Freight plays a vital role in the national, state, and local economy. But its specific contribution is difficult to quantify, and the mechanism of impact of freight transportation investments on economic production is not clear. Traditional cost-benefit analysis focuses on the cost and benefits of building specific facilities at the project level. This is insufficient and underestimates the true benefits of freight as it does not take into account the multiplier effects that freight brings to the economy as a whole.

Freight movements connect markets and businesses from different regions and locations and improving the freight transportation system can significantly enhance the efficiency of freight trade and therefore stimulate regional economic growth. Improvements such as freight route improvement or freight service enhancement lead to more efficient truck deliveries through reducing travel time and costs and thus directly or indirectly influence the production costs of goods. Increased freight efficiencies could as well be translated into industry productivity and potentially influence economic growth, regional employment, or other socio-economic indicators. Therefore, it is necessary to better integrate freight transportation into the economic framework of the state of Florida. This is essential for decision-makers to make more informed decisions in investments in the freight transportation system and to better understand the interaction of freight and regional or local economy. Therefore, the primary goals of this study were to quantify the impacts of freight transportation on the economy.

Project objective(s)

Freight transportation plays a vital role in local and regional economy, but its economic contribution is difficult to quantify. Nationwide, most of the current economic analysis

frameworks employ the cost-benefit analysis on proposed transportation projects and mainly focus on analyzing the cost effectiveness of specific facilities at the project level for decision-making purposes. In addition, many states do not have separate tools to evaluate the economic impacts of freight-related projects. It is therefore insufficient and would underestimate the true economic benefits of freight transportation. Thus, to make more informed decisions on freight-related investment, further investigation is needed to better understand the internal relationships between the freight system and the economy.

The overall goal of this project was to develop an economic analysis framework and models to estimate the impacts of freight-related projects and investments on the economy at various levels. A post-processing tool is then developed to help quantify the economic benefits of freight projects and to assist the project prioritization process for the Florida Department of Transportation (FDOT) based on the Freight Supply-chain Intermodal Model (FreightSIM).

Research outcomes

In this research, we first conducted a literature review on the current state-of-practice in economic analysis of freight transportation. This literature review covers not only the United States, but also some European countries and Australia. In the second stage, based on regional economic models (input-output model), we developed a framework that integrates the Freight Supply-chain Intermodal Model (FreightSIM) and regional economic model to quantify the economic impacts of freight. The framework was then used to develop a Python-based software called Florida Freight Economic Impact Kit. To conclude, we provide two case studies and demonstrate the use of this tool.

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1 LITERATURE REVIEW

Urban agglomeration has spurred increased demand for freight movement, and freight transportation in turn acts as the backbone of urban and regional economy. However, a review of research from both academia and practice has indicated that the economic potential of freight transportation has been overlooked in urban settings while the major focus is on passenger transportation. Transportation economists are eager to understand freight transportation from freight network optimization, shipper cost saving or supply-chain saving (Dablanc, 2007; Seetharaman et al., 2003). The traditional economic impacts from freight transportation, as from Dablanc (2007), has been less investigated in an urban context.

Suppose that one or more links or nodes in the freight network are affected by external supply shock. How would the freight flows and trades among different regions react to the exogenous change? The answer to this question seems to rely on a transportation model which estimates transportation outputs that are useful for transportation planners in future transportation supply and demand planning. However, transportation demand models are not able determine the economic implications from these freight-related investments, or direct and induced impacts in the long run. Many transportation evaluation selection and screening tools at present put the transportation outcomes into a hierarchal or cost-benefit analysis framework (Wygonik et al., 2014), or combine transportation modeling with economic analysis. An important component for bridging the economic analysis framework with transportation demand modes is to monetize transportation outcomes, which the economic analysis tool would be able to use in further modeling. For instance, Wang et al. (2013) developed a tool that measures trade flow changes from a major disruption event and then calculates the long-term economic impacts. Freight accessibility is used in their research framework as the indicator of transportation network

changes and the proportions of accessibility changes is then translated into gross domestic product changes used in further Computable General Equilibrium (CGE) modeling.

1.1 Florida Freight Supply-chain Intermodal Model (FreightSIM)

The Florida Freight Supply-chain Intermodal Model (FreightSIM) is a new freight model, and different from traditional freight models. It assigns commodity flows into different freight transport modes and optimizes routes systems considering firm sizes, locations, costs, economic activities as well as other economic indicators. The model not only estimates highway in Florida but also provides information about different modes of freight transportation—FreightSIM includes multimodal networks of rail, airports, ports, and highways outside of Florida in the rest of the U.S. In addition to these, the model also includes distribution center locations.

The new statewide model includes more detailed demand analyzing process such as Firm synthesis, Supplier selection, Goods Demand estimation etc. which can capture driving forces in freight demand change and able to reflect the freight movement in real world. The basic modeling processes from the FreightSIM can be summarized as follows:

1. Firm synthesis: Synthesizes firms in Florida, the rest of the U.S., as well as an international sample
2. Supplier selection: connection between suppliers and buyers
3. Goods distribution: distributed goods flow among paired suppliers and buyers
4. Distribution channel: whether direct distributed or through intermodal facilities
5. Shipment decision: shipment size and frequency on paired buyers and suppliers
6. Modes: identification of trip modes and modal transfers

7. Network assignment: assign trips on the model network in an equilibrium framework

FreightSIM model is a simulation model that estimates the potential changes from an external shock on the existing network. Simulation outputs from the FreightSIM are very detailed and at disaggregate level including individual shipment records, modal trips, trip OD tables and assignment results on the network. The diverse outputs from this model provide useful information for different research purposes. It can provide different scenario tests of freight transportation investment including highway/rail/port capacity expansion, policy change or intermodal projects. It is also able to provide scenario simulation of transportation management, e.g., alternative scenario analysis of congestion mitigation.

1.2 RIMS II

RIMS II is a regional input-output model and has been applied to study direct and indirect economic impacts of a specific business on local economy. Horváth and Frechtling (1999) utilized RIMS II model to study and compare the economic impacts of tourism expenditure on local economy. They generated multiplier tables through three steps. First, a national direct industry by industry table, which contains amount of output required from each industry to each industry was prepared through using the Bureau of Economic Analysis (BEA) benchmark accounts for the U.S. economy. Afterwards, location quotients in a specific region are used to produce a regional industry requirements table from national table. The location quotients for a row industry indicate the degree to which the output is sufficient for the need of each industry. If the location quotient for a row industry is less than 1, this means the industry's output is not enough to supply other intraregional industries, therefore, imports of such products from other regions are needed and consequently, the multiplier in that industry needs to be reduced by adjusting national direct requirements table. At last, households' income and number of workers

in each region are updated and the regional direct requirement table is produced. The final demand multipliers, which is the ratio of earning or employment to the total demand, is a useful indicator for the local government, since it indicates how much of total earning can be generated by an increase of spending in a business.

1.3 REMI TranSight

The REMI TranSight is a tool for evaluating the economic effects of changes to transportation systems, allowing researchers to thoroughly analyze the comprehensive economic and operational effects of transportation projects. It is a dynamic model, which allows users to test alternative transportation changes and track the short and long-term impacts on economic activities such as jobs, income, population, and other economic variables. In addition, it integrates travel demand models with regional economic models and is constructed with extensive data reference to emissions, safety valuation factors and other data. It evaluates economic benefits from both individual cost savings and accumulated business benefits, thus projects in various size can be evaluated through the model.

The REMI TranSight is recommended to be used to analyze economic impacts from proposed transportation projects by researchers (Kreis et al., 2006; Konduri et al., 2013). Its capability to include data from transportation demand model and the ability to analyze climate change policies are some key bases of the application of this model. It is widely used by government agencies, consulting companies, and research institutions. Florida DOT calculates user highway benefits through the Highway Economic Requirements System model as inputs for the REMI model, and uses REMI to estimate economic benefits for the Five-year Work Program. In Maine, this model was used to determine the economic benefits from an east-west highway connector project to evaluate Canadian markets. The weakness of the REMI TranSight model is

its focus on highway networks and inability to consider properly rail freight and intermodal carriage (FHWA, 2015).

1.4 IMPLAN

IMPLAN is exclusively a non-survey based and regional input-output model. Similar to REMI, IMPLAN assumes a uniform national production technology and uses regional purchase coefficient to regionalize model parameters. Generally, three types of multipliers are used in IMPLAN, Type I, Type II and Type III multipliers. Type I multipliers account for the direct and indirect impacts of goods and services in a certain region. Type II multiplier also accounts for induced impacts made by employee's purchase. Different from Type I and Type II multipliers, Type III multiplier is based on non-linear consumption function, which means the marginal propensity is decreasing as income rises. IMPLAN builds its data from top to bottom, more specifically, national data serves as total sums of state data, and state data serves as total sums of county data. Employment and earning data comes from Bureau of Economic Analysis (BEA) and local government.

IMPLAN was developed by the Forest service of the U.S. department of Agricultural (Taylor and Group, 1993) and has been widely used in regional policy analysis. It collects secondary economic data from national, regional and local government reports and provides a user-friendly interface for building IO models (Rickman and Schwer, 1995).

Compared with RIMS II, IMPLAN needs to consider the deflation before entering into the program, also in order to express the results in current year dollars, it also needs to be inflated to be expressed the current year value (Lynch, 2000).

1.5 Economic and transportation indicators

From the literature review, models that evaluate the economic impacts from transportation investment can be summarized as: 1) sequential models to integrate spatial economic models with the transportation network; 2) non-sequential models to estimate the economic effect of the aggregate transportation investment without an explicit transportation model. Although these two different modeling frameworks have different procedures, models generally use consistent transportation and economic indicators, including vehicle miles traveled(VMT), vehicle hours traveled (VHT), gross domestic product(GDP), employment, etc. This chapter will introduce basic definitions of these mostly-used indicators in the literature and discuss how they are relevant to this study.

1.6 Transportation impacts

Economic impact outputs are estimated for income, employment, value-added, and GDP, and are expressed as multipliers from one industry to another industry. According to Weisbrod and Weisbrod (1997), three kinds of economic impacts exist in freight industry, they are direct impacts, indirect impacts and induced impacts. Direct impacts can be measured through changes in freight transportation service, such as expenditures and tax revenues directly come from operations of freight industry. Indirect impacts are defined as changes from suppliers of freight service, such as fuel, machinery and equipment suppliers. Induced impacts are determined by changes of households of employees from the freight industry service and direct suppliers of freight industry (Shin et al., 2015). All the three kinds of impacts can be measured through jobs, income and value added in IO models.

One of the important impact analyses on transportation system is to measure the economic impacts of improved infrastructure on freight industry. For instance, economic impacts of freight

industry for Miami-Dade County was measured by (Cambridge Systematics et al., 2011). In the study, direct, indirect and induced impacts were measured by IO analysis. A variety of data come from Port of Miami (POM), Florida's Highway Safety and Motor Vehicles office (FHSMV), Transportation Satellite Accounts (TSA), and Florida Department of Transportation (FDOT) etc.

The long-term benefits of infrastructure investment in transportation facilities are the improved freight transportation services. Improved travel conditions lead to cost saving in transportation and productivity enhancement. Four types of impacts exist in transportation system, they are: direct cost saving due to reduced time delay; direct cost saving due to enhanced safety and reliability; direct cost saving due to enhanced regional connectivity; additional growth due to improved accessibility. These four types of benefits will lead to direct, indirect or induced effects on households living costs, business operation costs, productivity and competitiveness. These long-term effects can be predicted through employment, business output, value added and worker's income in a long range, such as in twenty years after the investment plan initiated.

1.7 Economic indicators used in the literature

The relation between economic indicators and freight transportation has been analyzed from different points of view. Generally, the economic indicators include GPD, productivity, variety of costs, safety, and environmental impacts.

Gross domestic product (GDP) as economic indicator is most commonly used in freight modeling in a region or a country (Meersman and Van de Voorde, 2013). The close relation between growth in GDP and freight transportation was shown in the statistical analysis by Pastowski (1997). Many models need a conversion from money into freight, leading to GDP or other indicators of economic output are used to represent the trade patterns (Holguin-Veras et al., 2011). However, many researchers have pointed out that GDP is not the best indicator for freight

transport (Lehtonen, 2006; McKinnon, 2007; Meersman et al., 2013). Related research has shown that composition of GDP has changed and is still changing, and links between freight transportation and economic activities has been changed. The reasons for this is because of the globalization of the world economy and changing business behavior such as time-based competition and labor costs.

Regional economic and macroeconomic models have been applied to estimate relationships between infrastructure investment and productivity (Yu, 2017). Nadiri and Mamuneas (1998) found that capital investment in highways contributes to growth and productivity at the industry and even larger scale level. Kansas DOT and North Carolina DOT used the TREDIS economic model platform to evaluate the highway project's economic impacts. The economic indicators include employment, gross state product, personal income, and productivity. Michigan DOT used REMI economic model platform to explore the economic effects of transportation investments on personal income, employment, business sales, and gross state product. However, given the proprietary nature of these economic model platforms and the lack of complete transparency of the model, many states have not implemented the models (Wang et al., 2013).

1.8 Transportation indicators

Transportation investment leads to accessibility, connectivity and mobility improvement which subsequently have ripple effects on urban and regional economics. These changes could be summarized by direct impact measured by transportation costs, indirect and induced impacts measured by gross domestic product, employment, income, tax revenues or even spending. To calculate these changes, transportation inputs are always first monetized for economic analysis.

Of reviewed literature that incorporates transportation network/demand models with economic analysis models, multiple transportation indicators are used to bridge these two

different models, including transportation costs, shipper costs, accessibility changes or vehicle-miles traveled (VMT) changes. In relevant studies, VMT or vehicle-hours traveled (VHT) are probably the most commonly used indicators in different types of analysis. The official definition for these two terms are straightforward— that is, they are calculated as the total annual miles or hours of vehicle travel divided by the total population within a specific geographical area. Some research has investigated the relationship between VMT and economic development, suggesting higher economic activities could lead to higher VMT. In freight transportation literature, similar concepts are also proposed to represent shipper costs or freight activities including ton-miles or ton-values. For instance, Wang et al. (2013) used the ton-mile changes as the indicators of shipper costs and translates it into monetized values which in further modeling is used as a counterfactual for the computable general equilibrium modeling. Guzman et al. (2016) used a random-utility based multi-regional input-output model to model the impact from the introduction of Long Haul freight trucks on the economy. Generalized transport cost for freight is calculated and put back into the model to generate iterations.

1.9 Other impacts from the literature

According to The National Highway Traffic Safety Administration (NHTSA), safety performance measures are indicators that enable decision makers to monitor changes in the performance of transportation system against established facilities. Some indicators include counts and rates of fatalities, number of serious injuries or crashes, number of speeding-related fatalities, and public perception of safety and emergency response time etc. Safety performance measures can be organized into three categories according to NHTSA and Governors Highway Association (GHA): Core measures, which relates to the safety goals and objectives established as part of policy or planning process. These measures measure overall process, including

injuries, fatalities and rashes presented as numbers, percentage and rates. Behavior measures measure the safety response of a specific safety activity and outcomes, such as direct observation of safety belt use and vehicle speed. The third kind of measure is activity measures, which tracks implementation of law enforcement, media, educations to reduce crashes and injuries. In addition to the above classification, examples of infrastructure-related safety performance measure are usually included into transportation planning process, and may include: number of run-off-the-road crashes, Number of fixed object crashes, Number of intersection crashes, Miles of guard cable installed, Miles of rumble strips installed, Number of signs updated or warning signs installed and Number of intersections with improved signal timing (Herbel et al., 2009).

Freight transportation brings a variety of social, environmental problems, including air and noise pollution, traffic accidents, and green gas emissions. According to U.S. Department of Transportation, NO_x, PM and CO₂ are major pollutants emitted from heavy freight trucks, and since emission of PM is usually lower than detection limit, therefore PM can be ignored from emission table. Generally, NO_x emission ranges from 2~50 grams per mile, and NO_x emission ranges from 1,000~7,000 grams per mile, which depends on both the modes and types of trucks. According to (Bickford, 2012) study, freight trucks emission factors in grams per mile can be summarized as follows:

Table 1 Emissions factors for freight rail and freight trucks in grams per ton-mile

	January	July	
CO	0.0845	0.0828	EPA's MOBILE 6.2 Model
NO_x	0.0845	0.5404	
PMC	0.0845	0.0025	
PM_{2.5}	0.0845	0.0154	
SO₂	0.0845	0.0221	
NH₃	0.0845	0.0014	
VOC	0.0198	0.0192	
CO₂	71.28	71.28	

1.10 Economic analysis methodologies

1.10.1 Input-output model

Since systematic analysis of economic impacts must account for inter-industry relationships within regions, regional input-output (IO) multipliers, which account for inter-industry relationships, are useful tools for conducting economic impact analysis. Econometric and regional input and output models build interregional and inter-industry linkages by simulating interregional trade flows as a function of travel costs. A matrix of inter-industry and interregional parameters is measured and fixed as technical coefficients in the model. In general, IO models characterize interactions between various market actors, such as manufacturers of products and services. Industries are usually aggregated into sectors. IO model identifies flows of commodities and services among sectors within a single macro environment.

Since information provided by input-output tables is helpful to predict transportation demands, Voigtlaende (2000) utilized an economic model based on dynamic analysis of U.S. input and output tables to forecast commodity output, and a transportation demand model based on commodity outputs. In Voigtlaende's study, four final demand sectors in the economic model are personal consumption, government investment and consumption, exports, and imports. Commodities are further divided into nine intermediate sectors: food products, raw materials (such as minerals, stone, etc.) and waste low value intermediate and final products, fuels, medium value intermediate and final products, high value intermediate and final products, and three types of non-transportable commodities, which are expressed as small, medium, and high growth commodities.

Consequently, in projection of multipliers, intermediate multipliers and final multipliers are projected separately. In the economic model, time series data of GDP was applied with

regression models to get multipliers of final demand by commodity and sectors. By transforming commodity dollar values into commodity weight, expressed as dollar per ton, or dollar per ton-miles, the change of a certain commodity goods means the change of dollar per ton of goods, economic model can be related with transportation model. Since total output commodity cannot effectively measure transportation output, therefore, the author sums up total domestic produced goods and imported goods as total output of a commodity in transportable output. Based on the input-output tables and economic projection, the projections of commodity output were derived. Therefore, the commodities output and structure changes of economy can be derived.

1.10.2 Econometrics

Econometric modeling methods include traditional regression models and discrete choice models such as logit model (Vilain et al., 2010). The basic analytical tool for econometrics is linear regression model, which is one of the most widely used approaches in freight modeling (Cambridge Systematics and NCHRP, 1997). The reason is that linear regression model is relatively straightforward to implement, and model variables can be understood and interpreted easily (Holguín-Veras et al., 2002). Linear regression models can be used without investing in expensive software solutions, making it a popular applied methodology for states and municipal planning agencies. For example, the Flow Factoring Method (FFM) based on regression equations is widely used by state Departments of Transportation in the U.S. FHWA (2015) adopted Autoregressive Integrate Moving Average (ARIMA) models and linear regression model to forecast truck volumes. Seabrooke et al. (2003) considered GDP as explanatory variable to predict future freight flow for Hong Kong port by means of regression analysis. Woo et al. (2011) reported that about 13% of the total published literature used regression models for

seaport freight data analysis. In addition, some studies utilized linear regression methods to build truck trip generation models (Holguín-Veras et al., 2002; Al-Deek et al., 2000).

The discrete models are widely used in the transportation planning and are the foundation of many mode choice and route choice models. Several studies reported that discrete choice models such as logit models and probit models can help logistics managers to better understand how to prioritize transportation carriers (Maier et al., 2002; Danielis et al., 2005). De Jong and Ben-Akiva (2007) employed a multi-nominal logit model to describe the decision process for transportation choice and applied it to freight traffic in Norway and Sweden. They found discrete choice model can be used as both a causal and a policy-sensitive model for freight transport.

Econometric models are well suited to demonstrate the effect of economic cycles on transportation. The multivariate models reveal the statistical relationships between travel demand and various drivers, providing separate estimations of the influence of each of various factors on demand. However, the limitation of econometric models in travel demand forecasting is their limited ability to incorporate network changes, congestion, and mode or route choice in systematic fashion (Vilain et al., 2010). The deficiency in modeling network changes or capacity constraints on individual links has been the motivation for the development of hybrid econometric-network (HEN) models. However, econometric models are limited to its data requirement and its simplified economic estimation of the inter-relationship between different industry sectors.

1.10.3 Cost-benefit analysis (CBA)

Economic impact analysis in transportation could be categorized as: 1) the estimation of economic impact from transportation impact; and 2) the value of the economic impacts from

transportation projects. The use of these different approaches stems from the motivations of the impact of analysis (Kockelman et al., 2013; Yu, 2017).

The cost-benefit analysis (CBA) is an approach which is widely used in various places to directly measure the economic impacts from transportation projects. As a useful and fast tool for project selection and screening, CBA is usually used in combination with other tools such as ranking score analysis. The general framework of a CBA analysis includes:

- 1) Identify the project needs and constraints which should be clearly stated in the beginning of the project.
- 2) Analyze the base case scenario, or the no-action scenario, which is defined as the analysis of no major investment changes;
- 3) Define work scope including the level of analysis when all types of scenario analysis is not feasible
- 4) This step involves the analysis of different alternatives and their impacts on traffic or economy.
- 5) The last step involves the comparison between different alternatives and base scenario to calculate the cost-benefit ratio and evaluate the risks of taking different steps.

However, several issues have been identified in the literature suggesting that the Cost-benefit analysis may have flaws in estimating the economic impacts. The results from the CBA might be biased due to a partial equilibrium approach if there are government interventions and distortion of market prices. CBA is not able to simulate the market equilibrium, the fact of which can lead to an incomplete understanding of the impacts.

1.11 Empirical evidence of economic impacts of freight infrastructure investment

The contribution of transport infrastructure investments to the broader economy is a major question in transportation. Both microeconomic and macroeconomic analysis are utilized to estimate the effects of transportation infrastructure investment. Cost-benefit analysis (CBA) as a microeconomic analysis focuses on the improvements in the productivity of individual firms. For instance, in the basic CBA framework, highway infrastructure improvements reduce costs because of both distance reduction and congestion reduction. While macroeconomic model attempts to analyze the overall cost and output effects of investments in the national, state, or regional level (Lakshmanan, 2011).

Overall, several aspects of the productivity of economic sectors can be affected by transportation infrastructure investments, including labor, capital, technology. The measurement can be defined as the ratio of output per unit from input factors. The output elasticity represents the percentage change of output for a 1% change of transport capital stock. Three factors determine the costs of output in a firm, including the cost of different input factors such as labor, capital, etc., the level of a firm's output, and the stock of infrastructure capital. In practice, the quality of such estimated elasticities depends on the functional form which represents the production or cost functions. Most studies of production function in transport infrastructure measurement assume a Cobb-Douglas specification which imposes a priori restrictions on substitutability of factor inputs (Munnell, 1990). Later studies adopt flexible functional forms, such as trans-log and the Generalized Quadratic (Nadiri and Mamuneas, 1996).

The first study on exploring the linkages between transport and economy is reported by Mera (1973). This study found the contribution of public infrastructure, including transport and communications infrastructure, to aggregate private production. The author concluded that a 1%

increase in transport and communication infrastructure stocks led to 0.35% to 0.40% increase in the output of manufacturing and service sectors. Aschauer (1989) and Munnell (1990) used similar procedures to examine the relationship between public investment and output in economic growth, which received wide attention. In recent years, more studies have focused on the economic contributions of transport infrastructure with the framework of production and cost functions. Seethepalli et al. (2008) state that transport infrastructure is important for economic growth in East Asia, while Montolio and Solé-Ollé (2009) have similar conclusion that public investment in road infrastructure positively affects productivity performance in Spain. Donaldson (2010) points out that more investment in railroads can reduce trade costs and interregional price gaps and increase trade flows.

Although the economic models help to estimate the contribution of transport infrastructure investment in lowering production costs, increasing economic output, and enhancing the productivity of private capital, the causal mechanisms of how infrastructure improvements translate into output and productivity are still unclear. Thus, understanding the interdependence between transport infrastructure investment and economic growth will provide some guidance for policy actions.

1.12 Summary

In general, models from the literature that evaluate the economic impacts from transportation investment can be summarized as:

- (1) sequential models to integrate spatial economic models with the transportation network,
- (2) and non-sequential models to estimate the economic effect of the aggregate transportation investment without an explicit transportation model.

Sequential model has advantages in using outputs from transportation demand modeling and translating these outputs into economic modeling framework, while the latter is not able to connect the two distinct models. Therefore, by using information from the FreightSIM, transportation/freight outputs from different scenarios could be exported to be used in economic analysis.

Multiple approaches have been used in the literature to estimate the economic impacts from transportation investment or specifically freight transportation. However, while econometric models can provide with better prediction of economic growth in relation to transportation indicators, this approach is limited in its requirement for its large available data for analysis. In addition, econometric models are only able to provide predictions of some certain economic indicators while the inter-industry relationship can hardly be depicted through this method. CBA is another approach that is widely used in real world yet it is limited to its simplified analytical structure. In general, input-output is the most appropriate economic method which could be used in further modeling as it can describe the inter-industry relationship as well as provide future economic performance estimation—

1):IO model characterizes interactions between various market actors, such as manufacturers of products and services;

2): Same actors usually are aggregated into sectors;

3): IO model identifies flows of commodities and services among sectors within a single macro environment.

4): The economic multipliers from IO model can be used in estimating macro-economic indicators.

In next steps, transportation indicators will be selected as the variables from the FreightSIM and input-output model will be mainly used to translate and incorporate those indicators into the economic analysis framework.

2 CASE STUDIES

Freight transportation services promote economic development through connecting people, business, and resources in various places. Although numerous cost-benefit analyses of transportation investment have been conducted to study the economic benefits of investing in a specific facility at a project level, the economic contribution of freight transportation to a specific industry is difficult to quantify, and the mechanism of impact of freight transportation investments on economic production is still unclear. The goal of this project is to quantify the economic impact of freight transportation, and to develop an application integrated with FreightSIM. The following report is laid out as follows. The researchers first conduct several case studies from United States, Australia, and Europe and then summarize the advantages as well as disadvantages from the tool or research framework applications. The report finally provides conclusions.

2.1 Application of transport economic development impact system

2.1.1 Introduction of TREDIS

Transport Economic Development Impact System (TREDIS) is an “analysis framework” that spans economic impact analysis, cost-benefit analysis, financial analysis, as well as freight impact analysis. TREDIS can be applied for all modes, including passenger and freight transport via aviation, marine and rail mode, truck, car, bus, bicycle, and pedestrian travel. It provides a consistent system for applying the different forms of economic analysis across space, time and elements of the economy. Transportation planners and policy analysts can easily use the system to conduct analysis and quickly obtain the understandable results.

TREDIS has been widely used in the U.S., Canada, and Australia. There are many success stories and case studies already. For the U.S., there are more than 10 State Transportation Department

(e.g. California, Michigan, Maine etc.) having used this tool to assess the economic impacts of transportation projects. For Australia, TREDIS was previously used for the Bus Rapid Transit (BRT) and a national highway upgrade program. TREDIS can be applied in wide range of ways and there are many cases spanning highways, airports, seaports, freight railroads and high-speed trains.

2.1.2 Workflow of TREDIS

TREDIS is an integrated system that does not require any other analysis tools. Yet some elements in the system can be replaced if the users want to use their own tools. Unlike “black box” method, the components of TREDIS is quite clear and well-defined. The key elements and workflow of TREDIS are below:

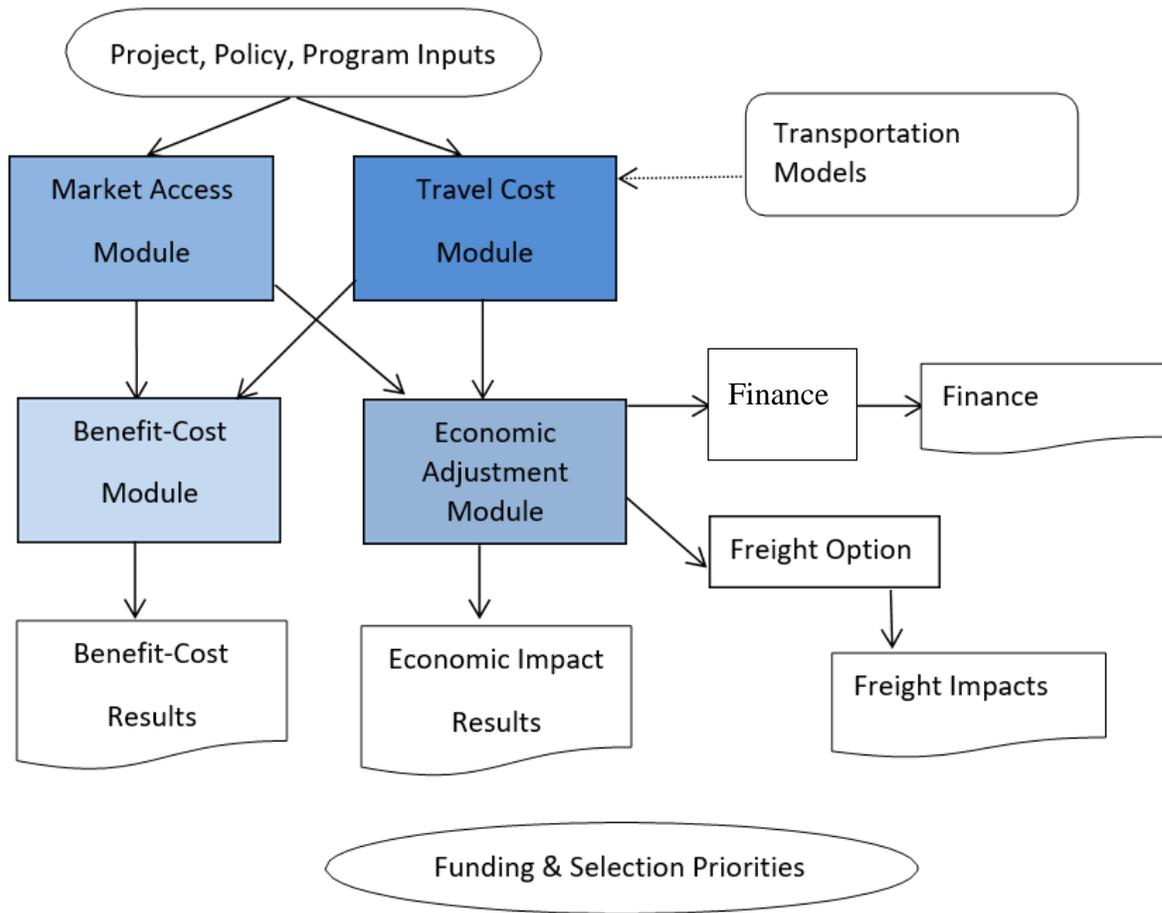


Figure 1 Work flow of TREDIS

TREDIS has four interconnected modules, including Market Access, Travel Cost, cost-benefit analysis, and adjustment.

- The Market Access Module estimates the agglomeration and economies of scale due to travel time savings and transport cost deduction.
- The Travel Cost Module estimates the travel efficiency changes and direct cost saving for household and business travel based on the base case or a transport project/improvement.
- The cost-benefit estimates the net present value of project benefits and costs. The separate finance module estimates the revenues, expenditures and cash flow due to the change of

transportation and economy. The separate Freight Module estimates the freight change due to a project or program's impact on economy.

- The economic adjustment module uses a dynamic, multi-regional economic-demographic model to estimate economic effects, including gross domestic product (GDP), employment, and income growth.

2.2 Case study of bus rapid transit in Australia

2.2.1 Background

The Northern Beaches BRT project in Australia was designed to provide a public transport service that more directly connects major residential centers of the Northern Beaches area to urban employment centers and specifically the Sydney central business district(CBD). BRT can provide a form of mass transit with the flexibility and relatively low cost of buses and benefit the environment. By taking the different mixes of service, quality of stations, dedicated roadway and vehicles and real-time information into consideration, the case develops five options below. The research group uses TREDIS to study the wider economy impacts in different portions and compares the results of different options.

Options considered for the Northern Beaches pre-feasibility study:

- 1: Bus Priority Improvement -- Upgrade existing kerbside bus lanes to 24 hour
- 2: Median BRT -- Segregated median BRT lanes and local buses on the kerbside
- 3: Kerbside BRT -- Segregated kerbside BRT lanes and passing bays at all bus stops
- 4: BRT with Bus Tunnel -- Kerbside BRT on Pittwater Road and bus tunnel under Military Road
- 5: North Side interchange BRT -- Segregated kerbside BRT lanes with rail interchange at N. Sydney

Figure 2 Options considered for BRT

2.2.2 Application of TREDIS framework

The project conducted the cost-benefit analysis (CBA) and Economic Impact Analysis (EIA) with TREDIS. The process used for applying TREDIS is shown below.

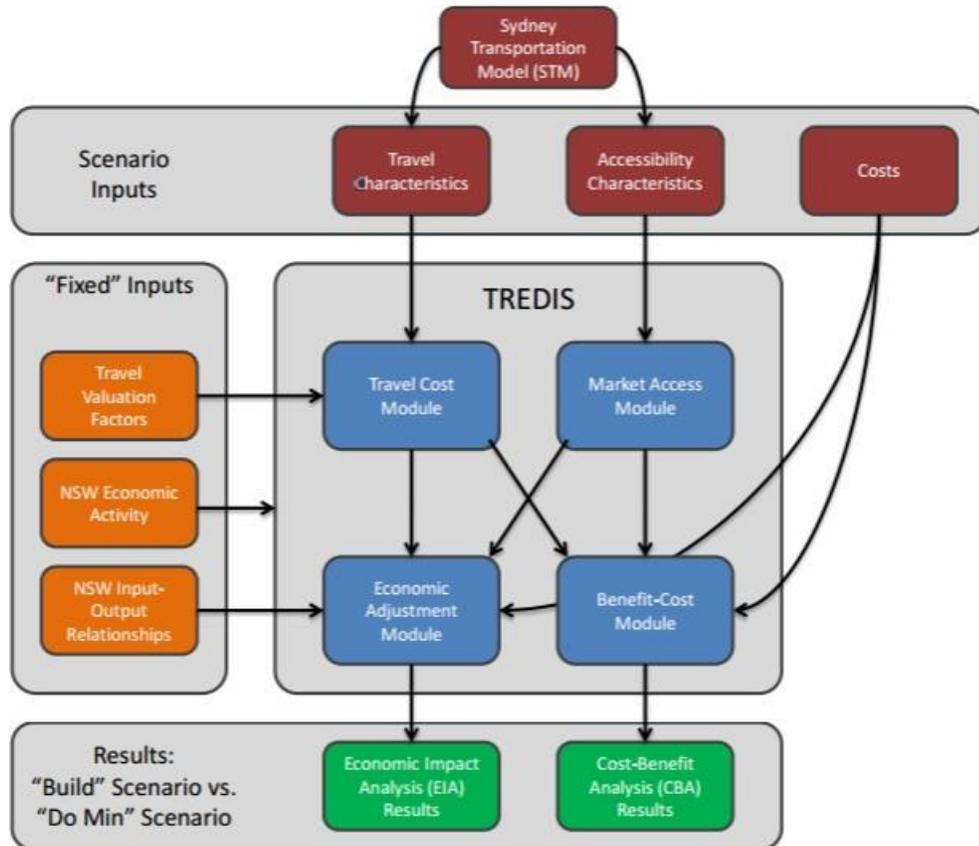


Figure 3 Application of TREDIS framework

The “Scenario Inputs” includes the characteristics of the do-minimum option and five BRT options. In the Scenario Inputs, the travel data includes trips, distance, travel time, tolls and fares, congestion levels, crowding levels, and reliability. These measures were estimated from two travel models: Sydney’s Strategic Transport Model (STM) and the Freight Movement Model (FMM). The Accessibility inputs reflect the additional effect of travel times and congestion on the “effective density” of activities within the regional economy which were calculated using zonal employment data and inter-

zonal travel times within region. The cost includes predicted the cost of construction, maintenance and operations over time which are provided by Transport for New South Wales (TFNSW).

The “Fixed “inputs are factors that remain constant for all scenarios and include factors for determining the costs of travel, including travel time, vehicle operating costs, accidents, and emissions. The data in NSW Economic Activity are economic data. The data in NSW input-output Relationships describes inter-industry relationships. The function of modules in TREDIS are explained in the second part of this section. With input data, the TREDIS modules generate the cost-benefit, economic impact, and fiscal impact results.

2.2.3 Results

2.2.3.1 Cost-benefit analysis

Study results regarding the cost-benefit ratio (BCR) are shown below.

Table 2 CBA results: alternative views

	(A) Traditional BCR <i>Pre-feasibility Study</i>	(B) Traditional BCR <i>ITLS/EDRG analysis</i>	(C) BCR mark-up for Wider Econ Benefits
1. Priority Improvement	0.67	1.24	23%
2. Median BRT	0.71	0.71	23%
3. Kerbside BRT	0.62	0.62	23%
4. Bus Tunnel	0.38	0.66	16%
5. North Side Interchange	0.67	0.85	18%

In the table, Column A shows the final CBA results issued by TFNSW in 2012, the numbers cover only traditional benefit measures (time, cost, safety, and emissions). Column B shows the CBA results from the 2012 study for the BCR (Institute of Transport and Logistics Studies(ITLS) and Economic Development Research Group (EDRG). Column C shows the BCR markup that would result from adding wider economic benefits. The BCR methodology sets the stage for further

consideration of wider economic benefits and interest in EIA results to see if strategic goals are being met.

2.2.3.2 Economic impacts across time

Table 3 Long-term economic impacts by investment option as of 2036

	Jobs	Worker Compensation	Value Added (GRP)
1. Priority Improvement	3,937	\$ 225 million	\$ 335 million
2. Median BRT	3,813	\$ 218 million	\$ 324 million
3. Kerbside BRT	3,829	\$ 219 million	\$ 326 million
4. Bus Tunnel	5,488	\$ 316 million	\$ 471 million
5. North Side Interchange	4,263	\$ 241 million	\$ 359 million

The numbers in the table reflect the cumulative effect of an increase in annual economic growth each year over a 20-year period.

2.2.3.3 Others

TREDIS also gives the results which include a spatial pattern of economic impacts and economic impacts across sectors of the economy.

2.3 The case study in California

2.3.1 Background

The California Transportation Plan(CTP) is a statewide, long-range transportation plan that will guide transportation decisions and investments in the 21st Century. The CTP provides a policy framework for meeting statewide transportation needs. It defines goals, policies, and strategies to achieve their collective vision for California's transportation future. The plan envisions a sustainable system that improves mobility and enhances their quality of life. The key to this vision is considering "the 3 E's" - a prosperous economy, quality environments, and social equity. California DOT selected TREDIS for the economic element of the broader modeling and policy assessment process, drawing inputs from the California Statewide Travel Demand Model and the California Freight Forecasting Model. The TREDIS economic impact analysis is being

complemented by consideration of environmental impacts using the Emissions Factor Model. Overall economic results are being generated in terms of jobs, income, Gross State Product and freight flows. This multimodal planning process was designed to comply with State law SB 391 which calls for the Department and its statewide transportation plan to address economic development (including productivity and efficiency for the movement of people and freight), and the California Global Warming Solutions Act of 2006, which calls for strategies that reduce greenhouse gas emissions.

In previous CTP documents, economic consideration was limited to identify the impacts associated with financial investments in transportation infrastructure projects and discussing transportation-dependent industries. For example, input-output (IO) models are commonly used to assess the potential economic impacts of transportation infrastructure projects. Investments in transit and highway infrastructure projects translate into short-term increases in jobs, incomes, and output (GSP). Another metric used in the past is the number of jobs in travel related industries. The North American Industry Classification System (NAICS) reports transportation-related jobs in nearly all major industry categories reflecting the wide span of impact.

Economic consideration in the CTP 2040, unlike previous documents, incorporates a more comprehensive analysis. California DOT attached more importance to the wider economic impacts of proposed transportation investment and policy strategies. So, they selected TREDIS to make the economic impact analysis of CTP 2040. The emphasis of the CTP 2040 analysis focused on the impacts of travel costs, market access, and economic adjustments. The travel cost impacts on households and industries are evaluated for their spending and productivity impacts. Cost savings, or dis-savings, from transportation investments or policy decisions, translate into changes in household spending patterns and productivity impacts on industries. TREDIS

measures how households and industries respond to changes in travel due to investment and policy changes. Additionally, TREDIS evaluates the direct changes in productivity or regional economic activity beyond the change in travel times or travel costs for users of the transportation network. These include increased production from business migration, increased labor productivity from agglomeration economies and increased international exports from improved access to international gateways.

2.3.2 Application of TREDIS in the analytical framework of CTP 2040

Figure 4 shows the modeling process of the CTP 2040. The inputs of TREDIS are from the outputs of California Statewide Travel Demand Model (CSTDM) and California Statewide Freight Forecasting Model (CSFFM). The CSTDM outputs several performance measures (Vehicle Miles Traveled (VMT), Vehicle Hours of Delay (VHD), trips, mode split, etc.) and the CSFFM outputs commodity flow by tonnage and mode. Different Policy Scenarios can be reflected in different outputs of the CSTDM and the CSFFM.

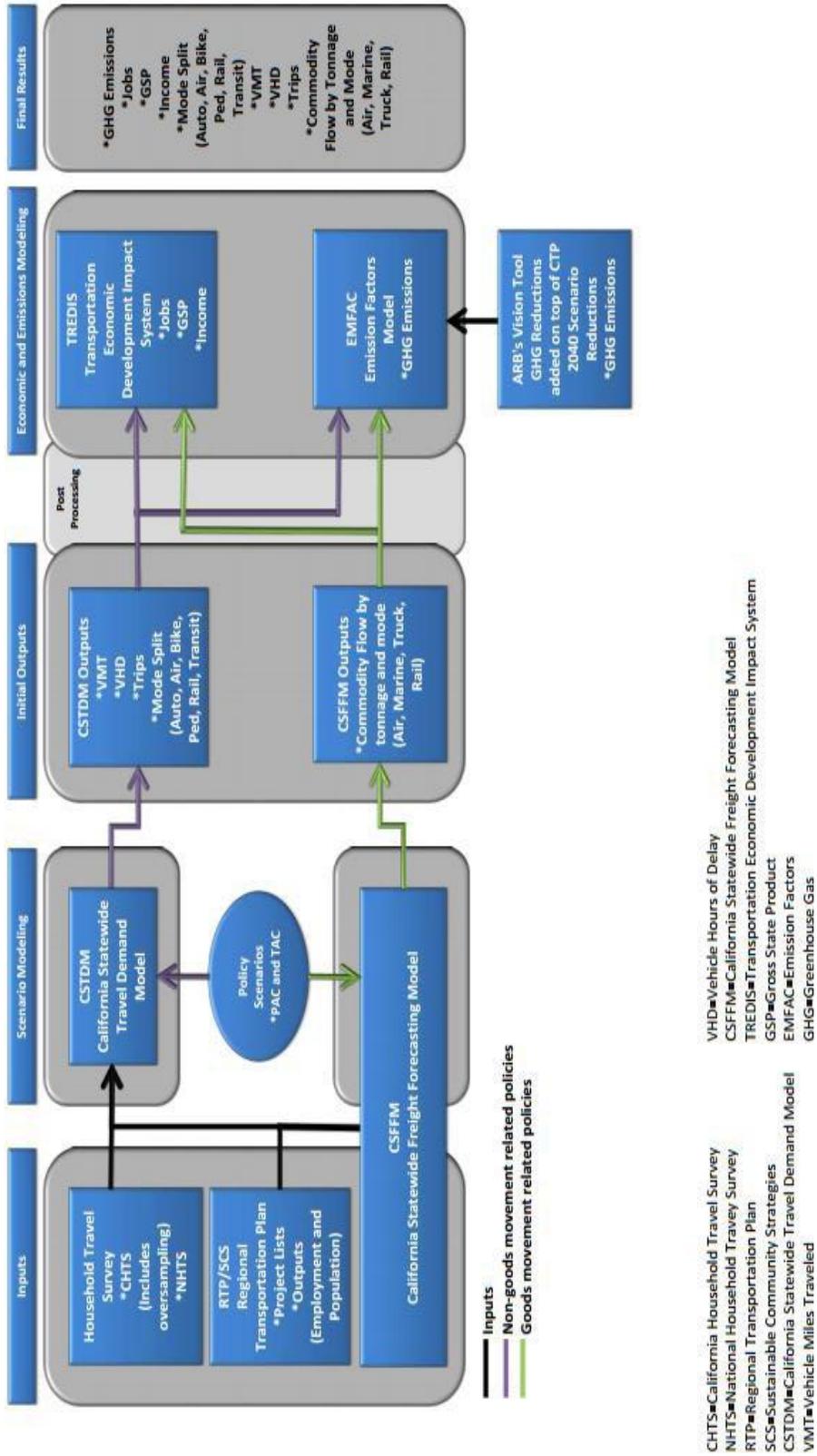


Figure 4 CTP 2040 modeling process

Putting the outputs of the CSTDM and the CSFFM into TREDIS, TREDIS can output four metrics including total Employment (jobs), total annual wages (worker income), total annual value added (regional GDP) and total annual business output (value of production sold). These outputs contribute to assess the economic impacts of CTP 2040 and rate the alternative transportation projects.

2.3.3 Limitations of using the TREDIS in this case

There are two limitations of using the TREDIS. First, the analysis does not include key considerations such as land use and transportation infrastructure expenditure impacts because of limitation in capacity of the CSTDM to address land use impacts. Second, limitations exist from the application of the CSTDM and the interpretation of the results. For instance, the CSTDM assigns transit, bicycle and pedestrian trips, but does not apply distance or time traveled as it does for passenger and commercial vehicles. From an economic assessment point of view, travel savings are difficult to assess.

2.3.4 Advantage and disadvantage of TREDIS

Advantage

- TREDIS have the capacity to predict longer term changes in the economy.
- Seamlessly combined transport costing and economic impact analysis enabling transportation economists and planners to undertake economic impact analysis without advanced computable general equilibrium(CGE) modeling skills.
- Can be subscribed online.

Disadvantage

- Although TREDIS is useful, it is expensive. TREDIS is a commercial software. You must pay for it when you use it each time.

2.4 Determining highway truck-freight benefits and economic impacts for Washington State Department of Transportation (WSDOT)

2.4.1 Introduction

Washington State Department of Transportation (WSDOT) has a long mobility project prioritization process which employs cost-benefit analysis (CBA) for project assessment. However, the existing framework from WSDOT does not account for trucking related benefits associated with highway projects. Therefore, the project assessment has incomplete information without providing freight-related economic benefits estimation. The established framework from any types of transportation project largely influences resource investment, therefore freight projects must be recognized and integrated into the existing project evaluation framework to fully evaluate transportation projects related benefits and cost (NCHRP, 2017). At this time, there is no known nationally or regionally accepted framework for analyzing the full range of freight-related impacts stemming from transportation infrastructure projects (Wang et al., 2013).

To fully capture transportation projects related effect, there is a clear interest from the policy makers that by what means they emphasize and select transportation projects. The recognition of including freight system performance measures at different levels including local, state, regional and national transportation plans has drawn attention among agencies in searching for efficient and applicable methodologies to assess freight-related benefits. Traditional cost-benefit analysis (CBA) has several limits when using to evaluating transportation related projects including: 1) it is not able to quantify macroeconomic effects from transportation investment; 2) it fails to consider the multi-sectoral relationship among different industries; 3) it fails to consider the equilibrium relationship between supply and demand. In response to these shortages associated with traditional cost-benefits analysis, WSDOT has developed an improved methodology to evaluate highway truck-

freight related project benefits. The methodology is also integrated to the state department of transportation's existing transportation project prioritization process.

The research framework of this integrated methodology was developed from dissection with the Washington State Freight Plan Technical Teams. The teams were asked to conduct a research to identify the most concerned impacts to the freight community from freight-related projects and to review the current state-of-art project selections. In addition, the teams conducted a review of current project prioritization approaches internally from WSDOT and provided information about what methodologies could be the best choices.

The research team has partnered with freight plan technical teams and has identified several crucial factors that will be potentially incorporated into the future framework development (Wang et al., 2013). The teams have members from different areas including: the first team focused on jobs, economy and goods; the second team focused on national and regional import-export activities; and the third team focused on the farm as well as manufacturing goods movement. Discussion among different teams has led to identification of measurable benefits and potential data sources including:

- travel time
- travel time reliability
- truck operating costs
- safety
- freight network connectivity
- network resiliency
- air quality and emission
- economic output defined by long-term jobs and regional gross domestic product.
- research framework

Factors including travel time, truck costs, emission, and economic output are included in the research framework. Safety is excluded as the WSDOT has an individual module to estimate the safety impact from freight-related transportation project. Network effects will be reflected through the measures of travel time and cost. In terms of travel time reliability, data limitation is a major issue, and the concept has also been excluded. Network resiliency has also been excluded due to a lack of data and definition consistency. The research team has emphasized that the integration of network resiliency and travel time reliability will be the next stage (Wang et al., 2013). The final selected indicators measure the freight-related benefits, including travel time, truck operating cost, environmental impact associated with emission, and regional economic impact in terms of long-run job and regional gross domestic product (GDP).

In the framework, regional travel demand modeling is the first step to estimate the travel time. The research framework first estimates the total truck travel time improvement by using the regional demand modeling from the WSDOT. The total travel time by truck is also defined as the truck vehicle hours traveled (VHT), which is calculated by multiplying the link volume and link travel time. A freight-related project is expected to improve the network performance and therefore reduce the system VHT. Therefore, the total reduction (which is also called the direct freight benefit from the transportation project) can be calculated. However, the research framework assumes that outside the study area, there will be no freight-related impact.

The next step of the framework involves the conversion of travel time savings to monetized values. In this step, a value of truck travel time is used by the team. The value was acquired by the team from the WSDOT who developed a generalized value based on driver wage and freight benefits. The operating costs monetized values come from the WSDOT, which calculated the value based on fuel consumption, fuel taxes, truck maintenance and repair, engine oil change, truck lease or purchase

payment, truck insurance premium, tire cost, and licensing and overweight-oversize permits (WSDOT 2009).

The value of emission conversion is evaluated based on the tons of emission from operating speed, total truck vehicle miles traveled, and emission rate (Wang et al., 2013). For the speed and VMT, they could be measured from the regional travel demand modeling. For the emission rate, it is calculated based on different information. The research framework has simplified the emission estimation which they only use the VMT and speed to calculate the total emission savings.

The next step involves the economic impact study modeling. The research framework considers different economic indicators including business, jobs, consumption and production. The framework applies the Washington State Regional Computable General Equilibrium model to convert output from the first step economic output. That is, the travel time saving, and operating cost savings are then utilized in the CGE modeling framework to calculate the long-run as well as the short run economic impact associated with freight-related project. The CGE model will generate information about job creation and regional gross output production change from transportation project.

The Washington State CGE model is developed by Professors David Holland, Leroy Stodick, and Stephan Devadoss (Lofgren et al., 2002), and the CGE model has been used extensively for evaluating statewide economic impacts from a host of policy changes (Holland and Devadoss, 2006). The model has information of different value flows among different economic sectors in the state. The modeling assumption is based on the traditional neo-classic economic theory where consumers and producers maximize their utilities and profits, supply factors are competed over, and demand is in an equilibrium relationship with consumption. In detail, the underlying assumption of the CGE model is Walrasian equilibrium, which states if all markets in each economy are in equilibrium, then any specific or individual market will also be in equilibrium and therefore a market clearing price and quantity exists

for any individual sector of the economy, as well as the whole regional economy (Wing, 2004). The CGE model requires social accounting matrix data which is similar to the traditional input-output data and has the value flow among different economic sectors. The CGE model is solved by third-party commercial software which is called the Generalized Algebraic Modeling System (GAMS) software and the PATH solver.

In all, based on the case study, the transportation project impacts could be evaluated in terms of direct freight benefit as well as long-run economic impact. The first step involves using the regional travel demand model to estimate the trucking related benefits in terms of travel time and operating cost reduction. By using standardized values obtained from different external sources such as the WSDOT, the reduction in transportation costs is then translated into the economic modeling framework to estimate the long-run economic impact from the transportation project.

2.4.2 Applications

The framework has already been integrated into the WSDOT freight plan which uses this framework to prioritize projects. The research team was not able to find the real project application. Instead, the research paper which describes the methodology provides a hypothetical case to help illustrate the framework.

A highway widening project on the major interstate highway in the state of Washington was selected to demonstrate the framework. This highway segment is a critical highway link for the region and served approximately 5,000 to 7,000 trucks daily in 2011 (Wang et al., 2013). It is also a strategic freight corridor carrying international and domestic trade. Considering this, WSDOT identified a widening project that supplemented the current four-lane highway with two additional lanes (one lane each direction). The segment length is approximately 10 miles.

The regional travel demand modeling was first run for the year of 2035 in terms of built and no-built scenarios. Therefore, the travel demand modeling could provide information in regard to the travel time savings, truck operating costs savings and environment impact associated with highway widening project. These savings were then translated into monetized values for the later stage modeling work.

Based on the travel demand modeling output, the total daily truck VHT would decrease by 295 hours in the built scenarios compared with the no-built scenarios. The travel time and truck operating cost savings were monetized using the truck costs per hour published by WSDOT. Based on the WSDOT, the framework uses \$27 and \$48 for the travel time and operating cost respectively. By calculating the yearly savings, this step generates a saving for next 20 years that the total saving would be \$9,200,000 in travel time savings and \$15,400,000 in operating costs.

The next stage is the CGE modeling. The data for CGE modeling comes from IMPLAN data and CGE model will be solved in the General Algebraic Modeling System software(GAMS). The case application estimated four scenarios including the short run as well as long-run for the state and a county which was selected by the research team. The short run scenario assumes that the capital is fixed across sectors and the long run allows capital to move among different sectors. Both the short run and long run scenarios assume that labor is mobile among different economic sectors which could be found from most of CGE models in the literature. The framework assumes that transportation project reduces freight travel time and operating costs and therefore the trucking industry becomes more productive. This could be finally captured by the productivity gains from the transportation project investment. Usually, running a CGE model to simulate a policy or external shock requires the definition of counterfactual to initiate the CGE model. The framework develops a trucking parameter which measures the productivity by using the Leontief-Constant Elasticity of Substitution (CES)

production function. The productivity change is measured by the change of cost savings from travel demand modeling divided by the intermediate expenditures. Since CGE model is a complicated modeling system, a black box, and involves hundreds of equations to reach production and consumption equilibrium, the report here will not describe in detail about the CGE modeling. Based on the calculation, the total productivity change for the state as well as the county selected are 0.26% and 3.23%, respectively.

Table 4 County-level results from CGE modeling

Sector	Initial Employment Level	Change in Employment Numbers		Change in Activity Quantity (%)	
		SR	LR	SR	LR
Agriculture and Forestry	3,993	4.6	14.5	0.021	0.361
Mining	255	0.1	0.2	0.005	0.078
Utilities	624	0.1	0.5	0.005	0.070
Construction	15,060	3.3	2.8	0.015	0.018
Manufacturing	14,046	26.8	45.8	0.133	0.325
Wholesale Trade	10,292	3.1	5.6	0.019	0.053
Retail Trade	30,532	8.0	9.6	0.022	0.031
Transportation and Warehousing	4,331	-2.4	-2.6	-0.038	-0.060
Transport by Truck	2,594	-45.0	-38.0	1.934	1.729
Information Services	3,362	0.4	0.8	0.004	0.022
Financial and Insurance	18,142	0.7	1.6	0.002	0.007
Real Estate	10,769	1.9	3.1	0.001	0.026
Professional and Technical	14,881	2.7	5.0	0.011	0.033
Management	2,687	2.1	4.1	0.069	0.154
Administration	11,940	5.2	6.5	0.034	0.054
Waste Management	357	0.2	0.2	0.025	0.068
Social Services	44,525	-0.6	2.5	-0.001	0.005
Arts and Entertainment	5,232	1.6	2.1	0.019	0.038
Food Services	17,216	3.6	5.8	0.014	0.032
Other (Including Government)	53,470	9.1	7.8	0.014	0.014

By running the CGE model, the final economic impact in terms of long run as well as short run could be calculated. Table 4 is from Wang et al. (2013) and reports the different scenarios of county level economic impact. (source from Wang et al., 2013; SR represent short-run scenario; LR represent long-run scenario).

2.4.3 Evaluation of CGE modeling

Compared with CGE model, input-output approaches use conventional methods which are well understood and widely used by academia, government and private sectors. The variety of CGE modelling approaches and lack of a standard methodology means that the model structure will likely be crucial for results.

Although CGE model considers different economic theories including profit maximization and cost minimization, labor mobility and supply constraints, CGE model is a black box which involves hundreds of equations to calculate the market equilibrium. The calculation of CGE model requires sophisticated economic knowledge to interpret and modify the model.

2.5 Measuring economic contribution of freight industry to the Maryland economy

The Maryland State Highway Administration has released a report that measures the economic contribution of the freight industry to Maryland's economy in 2010 (Shin et al., 2015). Economic impacts were presented as jobs, income, gross domestic product, and output generated by the services provided by the freight industry. The findings and methodologies of the study will help decision makers understand the role that each freight mode plays to make more informed decisions. The economic indicators used in this study – jobs, income, and GDP – can be used for public outreach to mitigate the negative perception of freight movement. While travel time reduction and increased business productivity used in past impact studies are useful performance measures, jobs and income measures appeal to citizens.

In general, eight industry sectors that rely on transportation industry include: agriculture, utility, construction, manufacturing, wholesale trade, retail trade, mining, transportation and warehousing. While these industries include not only freight transportation service, but also sectors use transportation to fulfill their inherent business goals. Therefore, IO models derived based on this

broad definition would over-estimate impacts of freight industry. A more stringent definition was used in this study: i) independent transportation service providers and ii) supporting service in private and public sectors. IMPLAN was applied to construct IO models and measure direct and indirect influence by two types of multipliers of freight transportation.

One of the main challenges in this study is the difficulty of obtaining the regional data necessary to implement IO models and capturing interregional flows of goods and service. To solve regionalizing the input and output data, the study relied on 1) publicly available data and 2) collecting some additional information by conducting a survey. At first, the IMPLAN's default value is estimated through national IO table by considering interstate flows of goods and services. Then, they used County Business Patterns (CBP) as primary data source. CBP reports overall economic situation on a yearly basis at the county or zip code levels, it includes: number of establishments, employment and number of payrolls by industry. Warehousing and transportation sectors (NAICS 48 and 49 respectively) having information related to freight transportation industry. Next step is to match CBP data with corresponding sectors of IMPLAN. CBP has 19,253 NAICS codes, while IMPLAN has 426 industry codes. The solution is to refine IMPLAN codes into detailed job categories (18535), each one corresponding to an industry in CBP.

To evaluate the economic impacts, first, employment is the number of jobs supported because of freight industry operations. Second, labor income is cash earning income, and third, value-added is the sum of additional values created from each stage of economic activity. Later, four scenarios were constructed based on IMPLAN data and historical data to explore freight transportation influence. This study does not consider freight flows, which was generated by transportation demand and traffic simulation model. To get the net benefit of freight transportation in a state level, travel demand model can be incorporated in the IMPLAN for comprehensive study.

2.6 *Freight demand modeling in European countries*

Several national model systems have been developed in European countries to forecast freight volume and flows. Several model systems include input–output (IO) analysis: 1) Italian national model system for passengers and freight, which uses 17 sectors and 20 regions and has elastic coefficients. 2) REGARD model for Norway, with 28 sectors, which produces demand used in the Norwegian National Freight Model System (NEMO). 3) Model for Belgium developed by ADE with 17 sectors, which produces demand used in the Walloon Region Freight model (WFTM). 4) Scenarios for European transport (SCENES) for passengers and freight and its predecessor Strategic Transport Research for European Member States (STREAMS), with 33 sectors and more than 200 zones in Europe and elastic coefficients. Moreover, the Dutch mode TEM-II and present SAMGODS (Swedish national freight model system) use a multi-sectorial IO table for the country. Based on regional share in employment and population, the IO table is regionalized and converted to tons unit (De Jong, 2004).

Freight transport forecasting is usually based on four-step modeling structure, which have originally been developed for passenger transport. The four-step in the context of freight transport are as follows: 1) production and attraction, the quantities of goods to be transported from multiple origins and the quantities to be transported to the various destinations. The output is usually in tones, while in the modeling stage, the dimension could be monetary units; 2) distribution, the flows in goods transported between origins and destinations (OD matrix) are determined; 3) mode split: the allocation in commodity flows to modes, for instance, train, truck, combined transport, inland waterways etc.; 4) assignment, after converting the flows in tones to vehicle units, they can be assigned to networks.

In the first stage, based on aggregated data, four types of models have been applied for production and attraction. a) Trends and time series models; b) System dynamic models; c) Zonal trip rate models; d) IO and related models. Besides other types models, IO models are basically macroeconomic models that start from IO tables. IO tables usually were developed by national central statistical office. Multi-regional or spatial IO tables is a special form of IO table, it can be scaled up and based on predicted sectorial growth for forecasting. Afterwards, by using fixed technical and trade coefficients (based on present production and trade patterns) or elastic technic and trade coefficients (estimated based on production ratio and transport costs), IO table can give future trade flows between regions. The multiregional IO models and the related multi-sectorial economic models used in the first step can be regarded as computable general equilibrium (CGE) models, establishing equilibrium in several related markets.

In the distribution module, the trade flows between origin and destination are determined based on measure of production and attraction and a measure of transport resistance. Measure of transport resistance is usually expressed as transport costs or generalized transport costs. While, in the Italian national model, the freight OD flows come from multiregional IO analysis with elastic coefficients, which means a multiregional IO model can supply both production/traction and distribution.

Various models either aggregated or disaggregated models can be applied to complete model split stage. FreightSIM can also be applied in this step. In model for assignment step, truck, rail or inland waterway transport trips are allocated to routes consisting of links of the respective modal networks. Assignment to the road network is in some cases done jointly with passenger traffic, since freight traffic usually is only a small fraction of total traffic (except near major freight terminals). Freight transport models used in European countries include: STREAMS (years simulated 1994, 2010, 2020), NEAC (1995, 2000, 2010, 2020), ASTRA system dynamic models (2000-2026), SCENES models

(1995, 2020), EXPEDITE meta model (1995, 2000, 2005, 2010, 2015,2020). Since no system dynamic models have been developed to predict outputs in the form of flows between a large number of origins and destinations, and network loads and sensitivities of policy changes, an integrated modeling system with two different resolutions would be necessary for future prediction: a high-resolution model with detailed information and network based with a number of interlinked modules, and a fast model based on system dynamic with low resolution but more straightforward for policy analysis.

Although many states of the art transport models used IO models, such as Italy national model, SMILE, and prototype freight transport model for Portland etc., a major disadvantage of using IO models are that trade flows are in monetary units, a freight transport model should produce in terms of tone, tone-km, and vehicle-km. Usually value ratios are used to convert monetary units to tones units, which are usually based on mean values from statistics.

2.7 Conclusion

Improving the freight transportation system can significantly enhance the efficiency of freight trade and therefore stimulate regional economic growth. Improved freight transportation efficiencies could also be translated into industry productivity and potentially influence regional economic growth, employment, average wage etc. In turn, economic growth also drives higher demand for freight transportation. Therefore, a holistic understanding of sector's contribution and the summed-up contribution of freight transportation to the economy of State of Florida would have more benefits for decision makers to measure and consider infrastructure investment decisions. This report has summarized several real-world applications of quantifying economic benefits from Europe, Australia and United States. In the next stage, a more detailed research framework with input-output model incorporated will be developed.

3 RESEARCH FRAMEWORK

3.1 Comparison of IO model with other models

There are several methods to quantify the economic impact of freight transportation. The most common methods are cost-benefit analysis (CBA), econometrics, and input-output (IO) model. CBA can estimate the economic impact from transportation impact and the value of the economic impacts from transportation. Econometrics method includes traditional regression models and discrete choice models. It has a basic analytical linear regression model which is one of the most widely used approaches in freight modeling (Cambridge Systematics and NCHRP, 1997). IO model is a framework to analyze the interdependence of industries in an economy. It could characterize the inter-industry relationships.

Although econometric models and CBA are widely used in analyzing the economic impacts of transportation, they have some flaws in freight demand analysis. The limitation of econometric models in freight demand forecasting is their limited ability to incorporate network changes, congestion, and route choice in a systematic fashion (Vilain et al., 2010). Moreover, econometric models are limited by their data requirements and their simplified economic estimation of the inter-relationship between different industry sectors. The limitation of CBA is that the results might be biased to a partial equilibrium approach if there are government interventions and distortion of market prices. CBA is not able to simulate the market equilibrium, which can lead to an incomplete understanding of the impacts.

Compared with the econometric models and CBA, input-output model can overcome some of their flaws. IO model builds interregional and inter-industry linkage through simulating interregional trade flows as a function of travel costs which can reflect the inter-relationships of different regions. In addition, IO model presents the economic impacts of the overall market equilibrium, rather than a

partial equilibrium. More importantly, IO model could calculate the multiplier effect, which cannot be estimated by econometrics and CBA.

3.2 Methodology

3.2.1 Input-output model

IO model is usually used in input-output analysis which is the name given to an analytical framework developed by professor Wassily Leontief in the 1930s. The purpose of the input-output framework is to analyze the interdependence of industries in an economy. Today the input-output models are key components of many types of economic analysis and input-output framework has become one of the most widely applied methods in economics.

IO model is generally constructed from observed economic data for specific geographic region. These economic data contain the fundamental information about the flows of products from each industrial sector, considered as a producer, to each of the sectors, itself and others, considered as consumers. The Input-Output transactions table (Table 6) reflects this fundamental information.

Table 5 Input-output transactions table

		PRODUCERS AS CONSUMERS								FINAL DEMAND			
		Agric.	Mining	Const.	Manuf.	Trade	Transp.	Services	Other	Personal Consumption Expenditures	Gross Private Domestic Investment	Govt. Purchases of Goods & Services	Net Exports of Goods & Services
PRODUCERS	Agriculture												
	Mining												
	Construction												
	Manufacturing												
	Trade												
	Transportation												
	Services												
	Other Industry												
VALUE ADDED	Employees	Employee compensation								GROSS DOMESTIC PRODUCT			
	Business Owners and Capital	Profit-type income and capital consumption allowances											
	Government	Indirect business taxes											

Source: Miller and Blair (2009)

The shaded portion of the table depicted in Figure 1 contains the information about interindustry exchanges of goods. The additional columns, labeled Final Demand, record the sales by each sector to final markets for their production, such as personal consumption purchases and sales to the federal government. The additional rows, labeled Value Added, account for the other (non-industrial) inputs to production, such as labor, depreciation of capital, indirect business taxes, and imports.

Basing on the Input-Output transactions table, we can get the basic equations $(\mathbf{I} - \mathbf{A})\mathbf{x} = \mathbf{f}$, where \mathbf{I} is identity matrix, \mathbf{A} is technical coefficients matrix which reflects information contained in the shaded portion of the table depicted in Figure 3.1, \mathbf{x} reflects the output of each sector, \mathbf{f} reflects final demand. In our project, we use these basic equations to calculate the multipliers which can reflect the economic benefits of transportation improvement including direct increase in production, indirect impact through inter-industry transaction and induced impact from local employees' consumption.

3.2.2 *Exogenous IO models*

In the usual form of the standard input-output model $((\mathbf{I} - \mathbf{A}) \mathbf{x} = \mathbf{f})$, the final-demand elements, \mathbf{f} , are the exogenous components and the economy's gross outputs, \mathbf{x} , are endogenous, which means that we can quantify effects of change in \mathbf{f} on \mathbf{x} through the standard input-output model but cannot quantify effects of change in \mathbf{x} on \mathbf{f} or effects of change in \mathbf{x} on \mathbf{x} . Since transportation investments can increase the production of the transportation sector, we assume that production of the transportation sector is exogenous. Therefore, we cannot use the standard input-output model to evaluate economic benefits of transportation improvements. Exogenous IO models can solve this problem.

3.3 *FreightSIM introduction*

The Florida Freight Supply-Chain Intermodal Model (FreightSIM) is a new freight model, and different from traditional freight models. It assigns commodity flows into different freight

transport modes and optimizes routes systems considering firm sizes, locations, costs, economic activities as well as other economic indicators. The model not only estimates highway in Florida but also provides information about different modes of freight transportation—FreightSIM includes multimodal networks of rail, airports, and ports, and highways outside of Florida in the rest of the U.S.. In addition to these, the model also includes distribution center locations.

The new statewide model includes more detailed demand analyzing process such as Firm synthesis, Supplier selection, Goods Demand estimation etc. which can capture driving forces in freight demand change and able to reflect the freight movement in real world. The basic modeling processes from the FreightSIM can be summarized as follows:

- (1) Firm synthesise: Synthesizes firms in Florida, the rest of the U.S., as well as an international sample
- (2) Supplier selection: connection between suppliers and buyers
- (3) Goods distribution: distributed goods flows among paired suppliers and buyers
- (4) Distribution channel: whether direct distributed or through intermodal facilities
- (5) Shipment decision: shipment size and frequency on paired buyers and suppliers
- (6) Modes: identification of trip modes and modal transfers
- (7) Network assignment: assign trips on the model network in an equilibrium framework.

FreightSIM model is a simulation model that estimates the potential changes from an external shock on the existing network. Simulation outputs from the FreightSIM are very detailed and at disaggregate level including individual shipment records, modal trips, trip OD tables and assignment results on the network. The diverse outputs from this model provide useful information for different research purposes. It can provide different scenario tests of freight transportation investment including highway/rail/port capacity expansion, policy change or intermodal projects.

It is also able to provide scenario simulation of transportation management, e.g., alternative scenario analysis of congestion mitigation.

3.4 Linking FreightSIM with Input-output model

This section will describe the approach to linking FreightSIM output to input-output models. A freight infrastructure project that reduces truck travel time and subsequently freight costs can be represented as an improvement in trucking operation that permits the truck transportation sector to become more productive with lower freight price at given level of labor and capital. These productivity, or efficiency improvement, could be realized through driving time reduction, congestion reduction or total vehicle miles traveled, etc. There are several transportation measures that could be utilized to represent the transportation system measures, including (1) the measure for transportation demand such as ton-miles, or passenger-miles and (2) the measure for measuring transportation efficiency such as vehicle mile traveled, vehicle hours traveled, etc.

3.4.1 Modeling from the demand side or the supply side of the economy

In this study, both two measures suit for the analytical purposes—that is, to analyze how freight network improvement could lead additional demand for transportation services, we could opt for the demand measures while if the study wants to focus transportation efficiency improvement, we could choose the efficiency measures. However, in this study, the research team found that any external changes on the freight network, such as building a new bridge or adding a new truck lane, would contribute to price change from the supply side of the economy initially. Therefore, modeling from the supply side of the economy, or by using the efficiency measures, is a more appropriate modeling assumption.

3.4.2 *Vehicle hours traveled*

Based on the available data provided by the FreightSIM, we used the vehicle hours traveled as the connector between the FreightSIM and IO model. The definition of vehicle hours traveled is the total travel time for trucks on specific links during a given period. It is computed as the product of the link volume and the link travel time, summed over all links,

$$\text{Link VHT} = \text{Volume of truck traffic} \times \text{travel time} \times \text{given time}$$

During the last step of FreightSIM modeling, which is similar to traffic assignment in conventional four-step demand modeling, FreightSIM allocates freight traffic to existing highway network to calculate the total VHT for each specific link. Since study scopes of this research are both county level and the state level, the traffic traveled time are extracted from the FreightSIM output files for study areas. For the following step, total VHTs for all of the specific highway links are aggregated by study regions.

3.4.3 *Conversion of FreightSIM output to monetized values*

The next step, after extracting and aggregating the total system VHT for study regions, is to convert FreightSIM to monetized values that could be directly put into input-output models.

From literature review, the research team has identified there are several ways for the conversion. First, a simple scalar or elasticity could be used to derive the new output level. For example, Seetharaman et al. (2003) calculated the ratio of the new Vehicle miles traveled to the old one. A pre-defined elasticity is used to scale the ratio as the scalar for new output based on the old sector output. However, this approach has limits. First, it is based on the pre-defined method to calculate the new total output and this measure might not be accurate and realistic to reflect the real change. Second, elasticity is also based on external sources which are arbitrary.

Another approach identified by the research team from the reviewed literature is the integration of regional travel demand modeling with economic modeling. As such, more realistic transportation output could be derived from the regional demand modeling. Once the output is obtained, monetized values such as the value of travel time could be used to convert the output to economic modeling variable.

3.5 Research framework testing

3.5.1 Scenario definition

One hypothetical scenario testing is selected to illustrate the overall process. The hypothetical scenario is defined as: Increase the capacity of Jacksonville port by 30% in total.

The modification was done in the FreightSIM and the input file for the port capacity, *F_data_flports*, was modified to increase the port capacity of Jacksonville port to 33.3 from 19.3. The following step is to run the entire process of FreightSIM model, including both of the module of passenger and freight network assignment. It is assumed that the increased port capacity will diverge more truck freight volume to port freight. Subsequently, there will be less traffic on the highway. The reduced traffic leads to less travel time and congestion. Eventually, the reduced travel time indicates more efficient freight operation and leads to increased demand for freight transportation. Two study areas were selected including the state and the Duval County. the analysis period between 2017 and 2035 is 19 years (For illustration purposes, we use 20 years as the analysis period). The projected 2035 regional TDM outputs of build and no-build scenarios were provided by FreightSIM, from which we calculated the changes in system total truck VHT to estimate the travel time savings associated with the port capacity increase. The estimated transportation related benefits were used as inputs to calculate the economic impacts the

input-output approach. Details of the FreightSIM output, economic impact analysis, and calculated results are presented below.

3.5.2 FreightSIM output

Table 6 FreightSIM output

Total VHT savings	Port capacity no change	Port capacity increase by 30%	VHT change
2035 output	No-Build Scenario	Built Scenario	
Statewide	125,926,432.3	125,929,187.3	-2,755.9
Duval County	1,702,307.0	1,725,873.2	-3,93.1

The FreightSIM was employed to evaluate the post-event traffic volume to calculate the freight truck performance. The TDM relevant to the test project was employed to evaluate the pre- and post-investment traffic performance, including the freight specific performance. The model is a supply-chain model like a conventional four step modeling. Segment-level truck VHT is calculated by multiplying the average travel time and the truck volume, and system total truck VHT is computed by adding together the segment-level VHT estimates by state level and the Duval County level. As is shown in the above table, the total VHT savings for the state level and county level are 110,222 and 393 hours, respectively. It could be seen from model output that after increasing the port capacity in the Jacksonville, although freight truck still has the largest share of the overall freight volume, freight traffic is diverged to water mode.

3.5.3 Direct freight benefit results

According to the FreightSIM outputs for the year of 2035, the system total daily VHT for truck reduction would decrease by 2599 hours for the statewide and 393 hours for the Duval County under the built scenario. This would, in the long run, lead to reduction in travel time and subsequently the truck operating costs. As mentioned before, the value of travel time is set as \$23 per hour, although it is flexible. The total estimated annual savings for the year 2035 for the statewide and county level are,

Statewide: $\$23 \times 365 \times 2755.9 = \$23,135,780.5$

Duval County: $\$23 \times 365 \times 393.1 = \$3,300,074.5$

We assume that annual benefits increased at a constant rate, and the total annual incremental savings estimated for each year was divided by the total study period (20 years). The initial value of benefit for the base year is therefore \$1,156,789. At the next step, the net present value (NPV) was calculated and the initial investment cost is set as zero since this is only a hypothetical case study. The net present value was then calculated by summing up the total annual benefits for estimated for 20 years study period. In net present value analysis, the discount rate is necessary. In the case study illustration, we used a discount rate of 3% and in tool development stage, such discount rate should be entered by users. The net present value calculated for statewide and the selected county was listed below,

Table 7 Estimated savings

Net present value (NPV)	System VHT change savings	Direct annual truck travel time savings for 2035	NPV
Base year 2017			
Statewide	2755.9	\$ 23,135,780.5	\$25,687,981.2
Duval County	393.1	\$ 3,300,074.5	\$3,664,118.95

The total truck savings for the 20-year study period for the statewide is more than 25 million dollars and as for the Duval County, increasing the port capacity leads to more than 3 million dollars savings.

3.5.4 Economic impact analysis

Reduction in transportation spending, or travel time cost savings, affects the production costs of freight-related economic sectors. These effects could be captured by the input-output modeling. We used data obtained from the software, IMPLAN, to calculate the economic impacts from the estimated freight travel time savings. The data for 2015 from the IMPLAN data

was used to represent the up-to-date economic structure. However, since economic structure is likely to remain stable for many years, using the cross-sectional data instead of time-series data is appropriate. The initial IMPLAN data has more than 500 economic sectors, of which we aggregated based on the North American Industry Classification System (NAICS) 2-digit classification.

Entering the direct transportation benefits, freight savings, to the input-output models as mentioned in the methodology section, derives economic impacts for total sectoral value added, total output, employment and income for the study areas. The statewide level results are presented in the following table,

Table 8 State-level results

Description	Employment	Labor income	Value added	Sectoral Output
Total	364.9	\$16,962,229	\$25,559,747	\$56,013,209
11 Ag, Forestry, Fish & Hunting	0.7	\$22,856	\$35,745	\$64,599
21 Mining	0.3	\$6,063	\$9,016	\$38,671
22 Utilities	0.5	\$58,313	\$259,864	\$565,115
23 Construction	2.6	\$111,817	\$184,622	\$422,687
31-33 Manufacturing	3.6	\$245,260	\$416,142	\$1,445,808
42 Wholesale Trade	7.8	\$645,344	\$1,252,443	\$1,966,928
44-45 Retail trade	19.7	\$657,030	\$1,055,057	\$1,591,814
48-49 Transportation & Warehousing	26.6	\$1,573,285	\$2,385,148	\$5,072,952
Freight Truck	172.4	\$7,569,357	\$9,203,516	\$26,253,486
51 Information	2.8	\$247,662	\$562,948	\$1,231,602
52 Finance & insurance	19.5	\$1,164,505	\$1,703,802	\$3,962,554
53 Real estate & rental	16.0	\$322,600	\$3,108,411	\$4,694,007
54 Professional-scientific & tech svcs	11.0	\$752,812	\$923,510	\$1,564,265
55 Management of companies	3.6	\$365,742	\$471,392	\$802,044
56 Administrative & waste services	23.2	\$777,870	\$964,253	\$1,528,512
61 Educational svcs	2.9	\$112,269	\$118,951	\$188,421
62 Health & social services	17.2	\$988,627	\$1,096,961	\$1,764,958
71 Arts- entertainment & recreation	3.7	\$122,440	\$194,023	\$316,562
7 Accommodation & food services	12.4	\$322,606	\$521,168	\$864,525
81 Other services	12.1	\$444,623	\$505,967	\$1,048,028
92 Government & non NAICS	6.2	\$451,149	\$586,807	\$625,673

Statewide analysis results suggest that the total employment increased by the savings would lead to additional 364 workers employed. The income will, correspondingly, increase by more

than \$16 million dollars over the 20-year study period. Of all of the sectors, freight transportation has the highest share of the increases in employment and income. In terms of the total value added and total sectoral output, for the overall 20-year study period, the direct freight savings would lead to more than \$25 and \$56 million dollars, respectively.

Results for the Duval County is presented in the following table, Table 4 Duval County results.

Table 9 Duval County results

Description	Employment	Labor income	Value added	Sectoral Output
Total	36.9	\$2,222,949	\$3,185,051	\$6,225,578
11 Ag, Forestry, Fish & Hunting	0	\$87	\$159	\$277
21 Mining	0	\$95	\$200	\$529
22 Utilities	0.1	\$11,979	\$36,275	\$67,163
23 Construction	0.2	\$10,809	\$18,332	\$40,180
31-33 Manufacturing	0.1	\$10,431	\$21,311	\$63,977
42 Wholesale Trade	0.8	\$63,171	\$124,223	\$197,056
44-45 Retail trade	2.1	\$67,946	\$107,686	\$164,774
48-49 Transportation & Warehousing	2.6	\$181,482	\$250,397	\$491,511
Freight Truck	18.4	\$1,248,984	\$1,545,426	\$3,368,076
51 Information	0.3	\$29,073	\$48,310	\$105,319
52 Finance & insurance	1.9	\$142,732	\$216,068	\$442,337
53 Real estate & rental	1.5	\$29,599	\$286,900	\$438,521
54 Professional- scientific & tech svcs	1	\$66,077	\$80,932	\$136,559
55 Management of companies	0.3	\$31,166	\$40,201	\$65,489
56 Administrative & waste services	2.2	\$83,582	\$104,406	\$150,376
61 Educational svcs	0.3	\$10,947	\$11,595	\$19,185
62 Health & social services	1.7	\$109,384	\$120,305	\$193,730
71 Arts-Entertainment & recreation	0.4	\$11,732	\$17,333	\$29,895
72 Accommodation & food services	1.3	\$29,163	\$47,787	\$83,276
81 Other services	1.2	\$43,066	\$49,576	\$105,600
92 Government & non NAICs	0.5	\$41,445	\$57,629	\$61,749

Reduced freight transportation due to port capacity increase also has many positive economic impacts on the Duval County. Similar to results for the statewide analysis, freight transportation in county level analysis also has the highest share of overall economic impacts. The direct benefit for transportation time savings for the Duval County is \$3.3 million and generates additional \$6.3 million dollars for the total sectoral output. It should also be noted that the estimation is based on single-regional input-output model and given the spatial spillover

effects from transportation investment. Other regions adjacent to the Duval County could also benefit from the project. This overall effect, therefore, is captured in the statewide IO models.

4 FLORIDA FREIGHT ECONOMIC IMPACT KIT

4.1 Introduction

Florida Freight Transportation Economic Impact Kit (FTEIK) is an economic analysis kit based on regional economic input-output model and Freight Supply-chain Intermodal Model (FreightSIM). The leading project managers are Dr. Zhong-Ren Peng from University of Florida and Frank Tabatabaee from the Florida Department of Transportation. The student researcher and software developer is Mr. Haitao Yu from University of Florida.

The kit is developed based on Python 3.0 scripting language. Note that FTEIK only runs on the Windows operating system, and to run the program file, you must have at least Windows 7 operating system in the computer. There is no additional requirement on the installation of the software, and it is a ready-to-use kit for different computers. The current version of Florida FTEIK is version 1.2.

The structure of the section is as follows. The second part will briefly review the research methodologies used from the last task as the support for the economic kit. The third part serves as the user manual for the kit.

4.2 Methodologies

The core of FTEIK lies in the combination of a freight demand model with a multi-sectoral economic model. Outputs from FreightSIM are converted into money values which are the inputs for the regional IO model to derive sectoral impacts for the studied economy. The kit also allows users to customize values for converting transportation outputs at the project level. The output from FreightSIM is vehicle miles traveled (VHT). It is assumed that freight transportation investment (e.g. new highway investment) would in the long run lead to more efficient freight traffic with less vehicle hour traveled on the highway links in the study area. The VHT savings

under different built scenarios represent the transportation network improvement. Detailed models could be found in the Task 3 report.

4.3 FreightSIM

Florida's FreightSim model is a supply-chain freight demand model integrated into the Florida Statewide Model (FLSWM). FreightSIM simulates freight movement between suppliers and buyers in the United States and provides detailed modeling for the state of Florida. By using commodity survey data with other freight-related data source, FreightSim produces a list of commodity shipments by destinations and origins, allocates shipments by values and modes, and eventually converts trips to daily truck trip tables assigned on the national and statewide transportation network. Due to its modeling capability, FreightSIM can provide freight planning insights in the several following aspects, including but not limited to:

- It informs freight investment decisions,
- It evaluates freight bottle-necks on the Florida statewide highways,
- It evaluates freight policies,
- It provides planners with regional freight travel for planning purposes.

4.4 Regional economic input-output model

Regional input-output (IO) model provides a way to estimate the economy-wide impact from an initial change in economic activity. The IO model is based on the idea that the initial change in economic activities will result in diminishing rounds of new spending from supplier to buyers for new production activities. However, traditional regional IO model has several modeling limits including its modeling simplicity in representing the economic interactions among different economic sectors and its modeling assumption in treating exogenous change as final demand change in the model. To overcome these modeling issues, this study used

exogenous regional IO model instead of the traditional IO model, in which the freight trucking sector is exogenized. The VHT savings are converted to monetized values for the overall study period by using net present values. The total saving is then entered in the IO model as the industry output change, which is more appropriate compared with final demand change. Several types of economic impacts could therefore be derived including industry output impact, employment impact and income impact.

4.5 *Florida Freight Transportation Economic Impact Kit (FTEIK) user manual*

This kit performs regional economic impact analysis based on the Florida FreightSIM. The underlying economic analysis methodology is based on regional IO model.

4.5.1 *Getting started*

There is no installation process or installation requirement for the kit. Users could locate the program icon from the following address in their own computers:

“~\FDOT Tool\build\exe.win-amd64-3.6\FDOT tool.exe”

Alternatively, users could create a shortcut of the program on the desktop to gain quick access. First, users could locate the original *exe* file from the link mentioned above and right click the program icon. Second, locate to *Send to* and finally click *Desktop (create shortcut)*.

These steps are also shown in Figure 5.

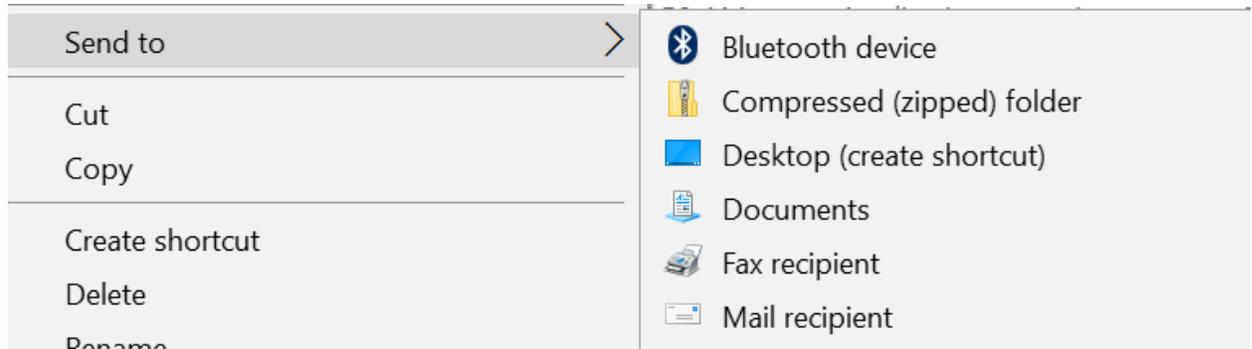


Figure 5 Create shortcut

4.5.2 Project window

Once users start the program, the kit will automatically load all the modules in the background. The project start window is shown in Figure 6. In the menu from the project window, there are two functions at current version. The first function allows users to read the manual for the software and the second function allows user to read the information about the software. These two functions are in the *About* in the Menu bar (Figure 7).

To start a new project, users should click the *NEW PROJECT* button in the project start window.



Figure 6 Project start window



Figure 7 Manual and software information

4.5.3 Project information

The Project Information window allows users to describe the project details, analyst names and analysis date. All the inputs are for project information use and will not affect the economic analysis and FreightSIM results. The window for the Project Information is shown in Figure 8.

Analysis date: This entry contains information of the date of the latest economic analysis. Users should use the latest date for conducting the analysis.

Analyst name: The analyst name entry is for the name of the staff performing the data input and economic analysis.

Project Description: The Notes section is for any additional notes in the analysis that may be of relevance to the economic analysis. For example, users could enter the project information, including the network change, the project name, etc. Users might also describe two scenarios including the built and no-built scenarios in this entry box.

After these inputs, user could click *Next* or *Back* for further operation. Note that, however, clicking either of these two options will not erase the data that have been entered in the kit. In addition, users will be able to access the information later when saving the output file. Users are also able to click *Back* in next operations to edit the information. This also applies to the following operations.

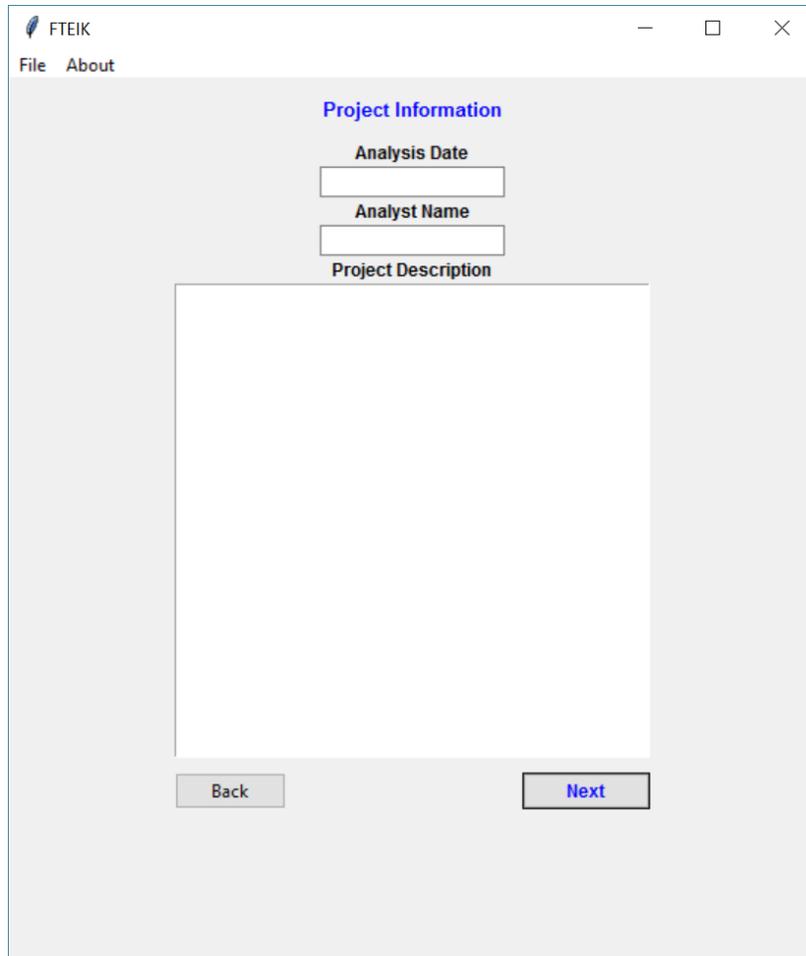


Figure 8 Project information

4.5.4 Project property

The project property, which is shown in Figure 8, is the key part of the entire economic analysis process. It allows users to customize their own values for converting outputs from FreightSIM and all the inputs from this window are required for further operation. If users are not sure what values to be used in this module, there is a *Help* function that recommends several values for the required inputs.

Choose study area: This is a drop-down list of the all of counties in Florida. Users could choose the study county from here. In addition, there is an additional option called Florida in the drop-down list. If users want to do statewide analysis, choose that option.

Choose forecasting year: This is a drop-down list of all the available forecasting years for the economic analysis. Note that these values (years) must match with the forecasting periods with FreightSIM. If users run FreightSIM at one forecasting year, the same year should be selected in this drop-down list. For example, different scenarios are run in FreightSIM for 2035 and in this drop-list user should choose 2035.

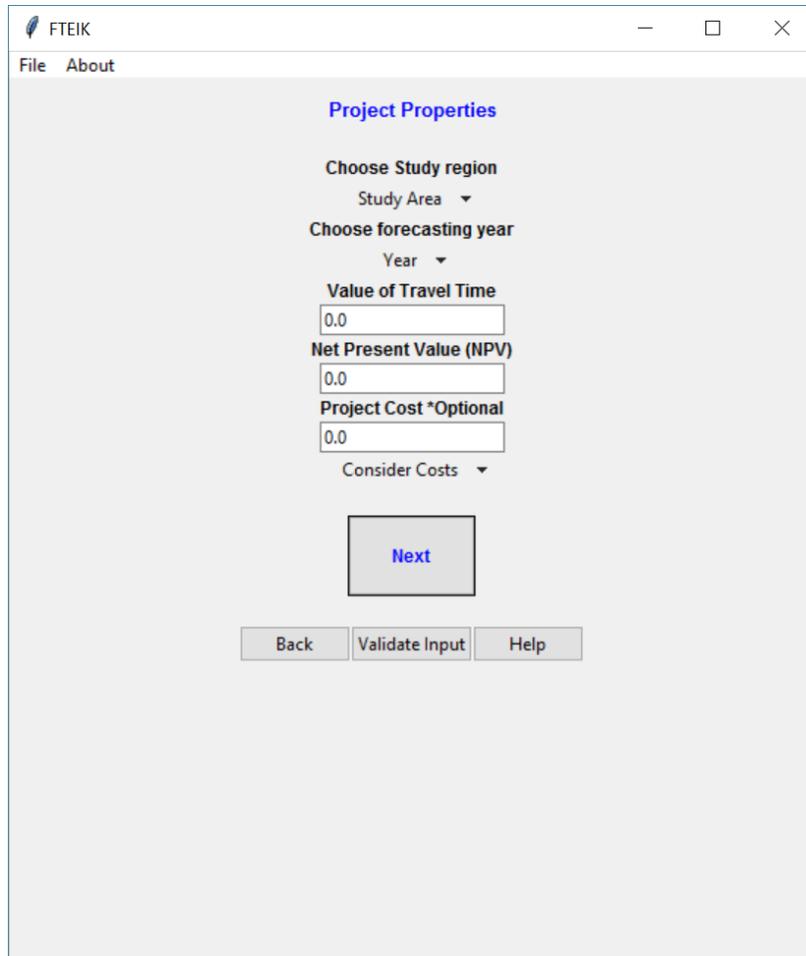
Value of travel time: This is an entry that users must enter to convert the VHT to money values. The value of travel time usually differs across regions and states. Users should enter the values based on their own research. However, the *Help* function recommends values of travel time if users do not have available values.

Net present value: This is an entry that users must enter to convert the VHT to money values. This allows the kit to sum all the money savings for each year to total savings based on the discount rate. The net present value usually differs across regions and states by projects. The ideal value for NPV is usually set as 0.04 yet if users decides to enter their own, it should be noted that the number must be smaller than 1 but larger than 0. Users should enter the values based on their own research findings. However, the *Help* function recommends net present values if users do not have available values.

Project costs and Consider Costs: These are two-option entries. If users want to include the project costs, users should enter the money values in the kit and choose *Yes* in the drop-down list. If users decide not to include project costs, users should leave the Project Costs blank and choose *NO* in the Consider Costs.

Validate Input: It is highly recommended that users should use this function to validate the inputs. The kit will automatically check several rounds for users' inputs and decide whether they are validated and appropriate. Wrong entries and inappropriate numbers will be marked in

by “**Attention”. For correct and appropriate entries, the kit will show the entry is validated. An example is shown in Figure 10.



The image shows a software window titled "FTEIK" with a menu bar containing "File" and "About". The main content area is titled "Project Properties" and contains the following elements:

- Choose Study region**: A dropdown menu labeled "Study Area".
- Choose forecasting year**: A dropdown menu labeled "Year".
- Value of Travel Time**: A text input field containing "0.0".
- Net Present Value (NPV)**: A text input field containing "0.0".
- Project Cost *Optional**: A text input field containing "0.0".
- Consider Costs**: A dropdown menu.
- Next**: A large blue button.
- Back**, **Validate Input**, and **Help**: Three smaller buttons at the bottom.

Figure 9 Project properties

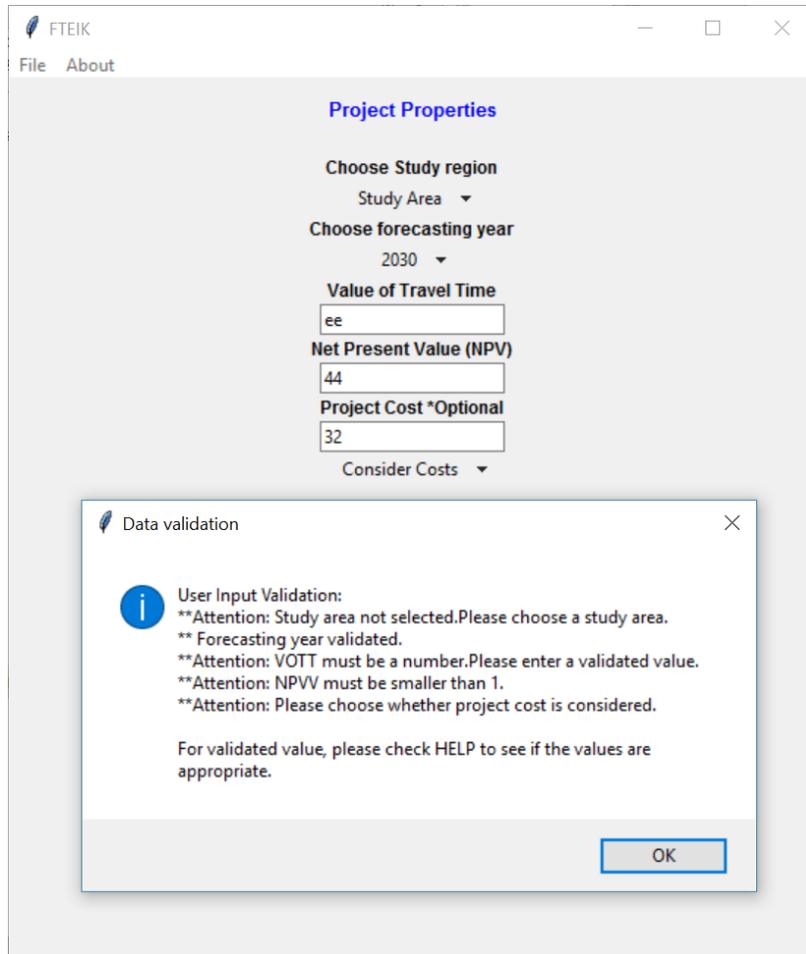


Figure 10 An example of entry validation

4.5.5 Scenario input

4.5.5.1 Built VHT analysis

After users enter the required values from the project information, they click *Next*, and the kit will begin the VHT analysis module (Figure 11).

At this step, users should finish running the FreightSIM for two scenarios, including the built scenario and no-built scenario for the year which is indicated in the Forecasting Year tab. After a FreightSIM run, users should locate its output folder and find the output file name Link.dbf. This file contains the VHT for each link of the entire statewide roadway network in Florida, and it is the output file for each scenario.

Users should remember the file path in the Link.dbf. To analyze the built scenario VHT, they click *Browse* for VHT link files. An open file window will pop up, and users should locate the built scenario Link.dbf in the window. After the Link.dbf file for the built scenario is selected, they click *Open*. A status window will pop up with the message ‘Please wait for VHT calculation...’ and users should click OK to start the calculation. This process will likely, depending on computer performance, last around 2-3 minutes and computers might even freeze due to large amount of operation. A successful run of VHT analysis will have total VHT calculated for the selected area and the VHT will be shown in the window labeled Built Scenario VHT. Once the VHT run is finished, users can see either a pop-up message or a message in the Calculation Status box suggesting that users can proceed for the next step (Figure 12).

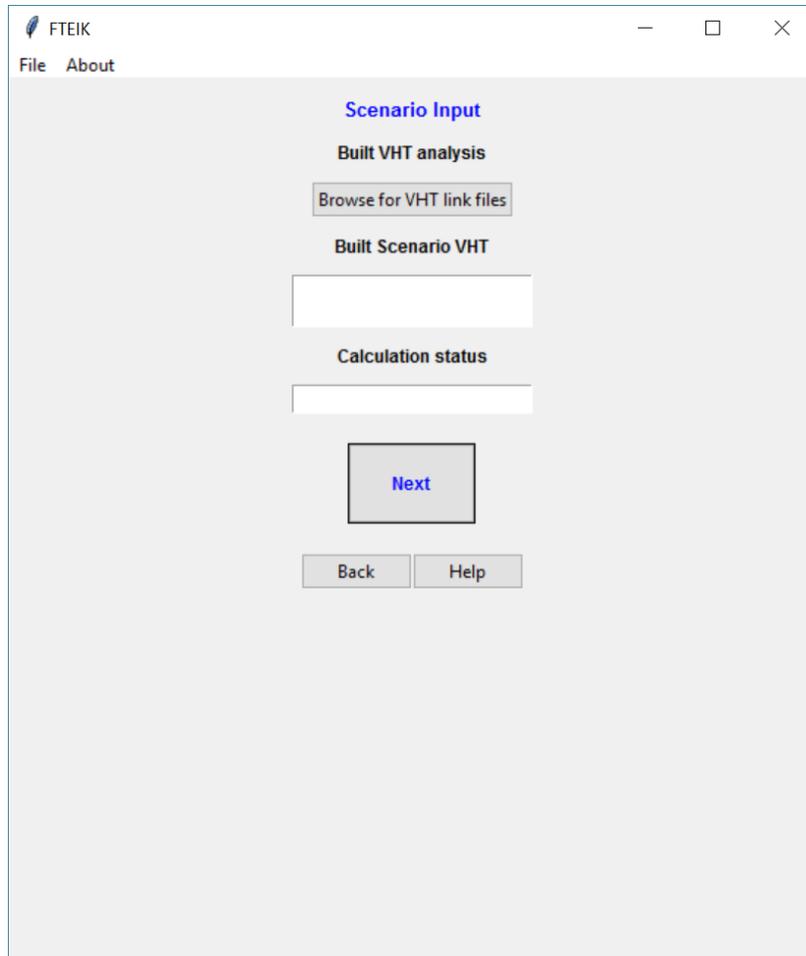


Figure 11 Calculate built VHT

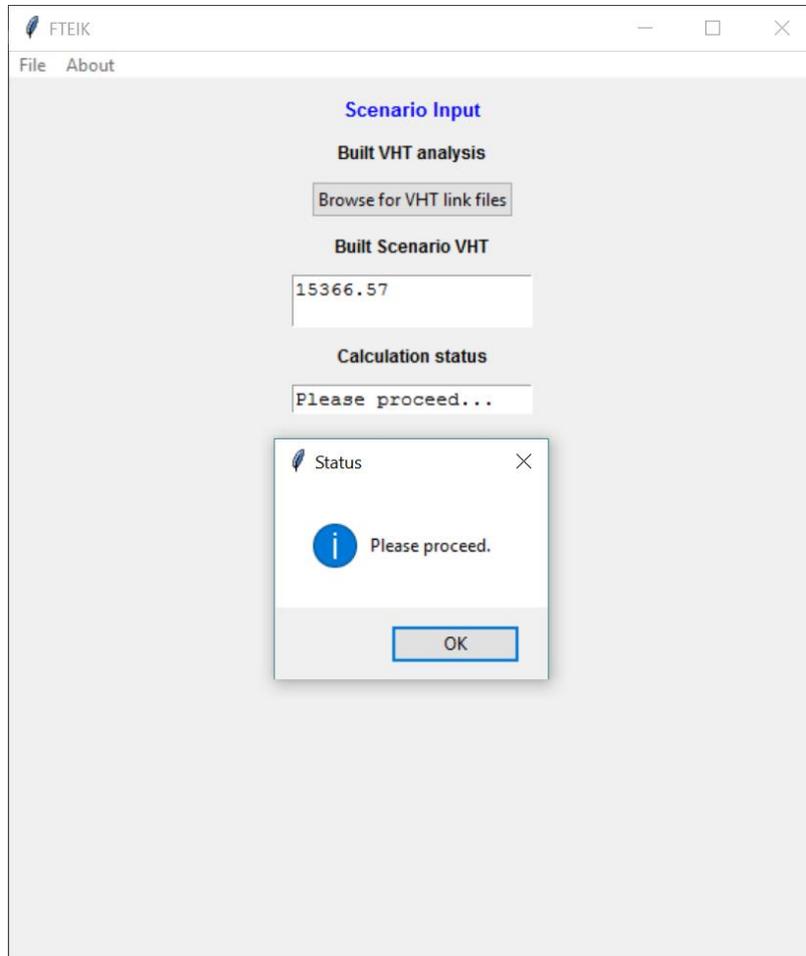


Figure 12 Message for successful run

4.5.5.2 No-Built VHT analysis

After users run the Built VHT analysis, click Next and the kit will begin the no-built VHT analysis module (Figure 13).

At this step, users should finish the FreightSIM run for two scenarios including the built scenario and no-built scenario for the year which is indicated in the Forecasting Year tab. After FreightSIM run, users should locate to its output folder and find the file name Link.dbf from the No-Built scenario output folder. This file contains the VHT for each link of the entire statewide roadway network in Florida and is output file for the no-built scenario.

Users should remember the file path in the Link.dbf. To analyze the no-built scenario VHT, click Browse for VHT link files. An open file window will pop up and locate the built scenario Link.dbf in the window. After the Link.dbf file for the no-built scenario is selected, click OPEN. A status window will pop up with message ‘Please wait for VHT calculation....’, and users should click OK to start the calculation. This process will likely, depending on computer performance, last around 2-3 minutes, and computers might even freeze due to large amount of operation. A successful run of VHT analysis will have total VHT calculated for the selected area, and the VHT will be shown in the window labeled Built Scenario VHT. Once the VHT run is finished, users can see either a pop-up message or a message in the Calculation Status box suggesting that users can proceed for the next step. This message box is the same with Figure 12.

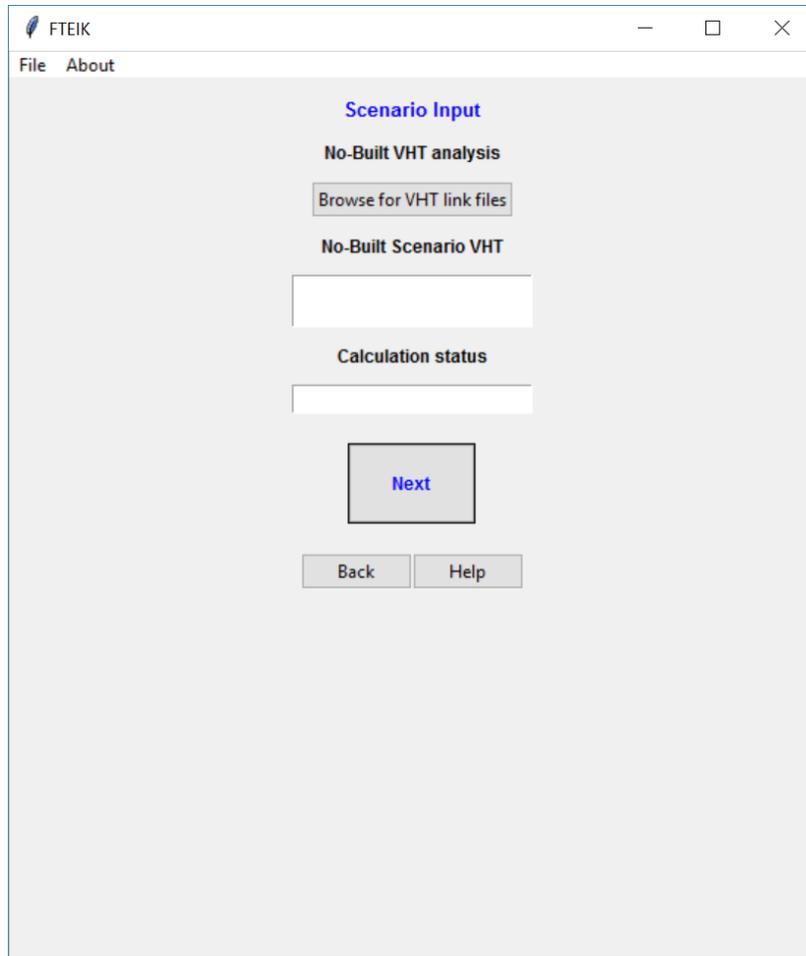


Figure 13 No-Built VHT calculation

4.5.5.3 Result window

Once the VHT analysis for both built and no-built scenario is done, users could proceed to analyze the economic impacts. The result window is shown in Figure 14. From the Results label, users could do the following operations:

- 1. Analyze Input:** This command will analyze the input including the customized values and VHTs for two built scenarios. Due to coding optimization, this operation is likely to take very short time. User input for the required values will be shown in the Project Input

window. However, the final results will not be shown in the window until the button Industry Results is clicked.

2. **Industry results:** This command will show the detail industry results with total economic benefits. Note that there are many ways to show the economic benefits. The kit uses three types of economic impacts including industry output impact, industry employment impact and economic income impact. Detailed results will be shown in the treeview window. Users would be able to view the results from there.
3. **Clear results:** This command will clear all the results.
4. **Save output:** This function allows user to save the results in a txt file with beautiful *tabulate* format.



Figure 14 Result output

5 CASE STUDIES

5.1 Introduction

Florida Freight Transportation Economic Impact Kit (FTEIK) is an economic analysis kit based on regional economic input-output model and Freight Supply-Chain Intermodal Model (FreightSIM). This report presents two case studies of the application of this kit.

The structure of the report is as follows. The second part will briefly review the research methodologies for the economic kit. The third part provides two hypothetical case studies to demonstrate the kit.

5.2 Methodologies

FTEIK has two main components including the Florida freight supply-chain demand model (FreightSIM) and Florida economic input-output model (IO). The kit allows users to customize values for converting transportation outputs at the project level and provide estimates for both state and regional level. The output from FreightSIM is vehicle miles traveled (VHT). It is assumed that freight transportation investment (e.g. new highway investment) would in the long run lead to more efficient freight traffic with less vehicle hour traveled on the highway links in the study area. The VHT savings under different built scenarios represent the transportation network improvement. Detailed models could be found in the Task 3 report.

5.3 Highway expansion project I

The first case study derives from the Florida 2040 Strategic Intermodal System (SIS) unfunded needs plan from District 3. The project aims to improve interstate highway capacity with additional lanes planned to be built on the I-10. This section will present the use of the kit and results estimates at the local level (county).

5.3.1 *Project description*

The hypothetical project will be in the Gadsden county in the Tallahassee metropolitan area. The project will be adding additional lanes to build 6-lanes on the I-10 interstate highway, which starts from the Florida State Highway 12 and ends at the west of U.S. 90.

5.3.2 *FreightSIM modification*

The following nodes are located to match the hypothetical project:

1. 36879-36717 (36717-36879)
2. 36921-37214 (37214-36921)

These two links were modified to increase both the capacity and lane numbers in the FreightSIM and the modification is shown in Figure 15 and 16 (Yellow highlighted lines in these two figures show the modified links¹).

¹ The red and green links are the regular highway links.

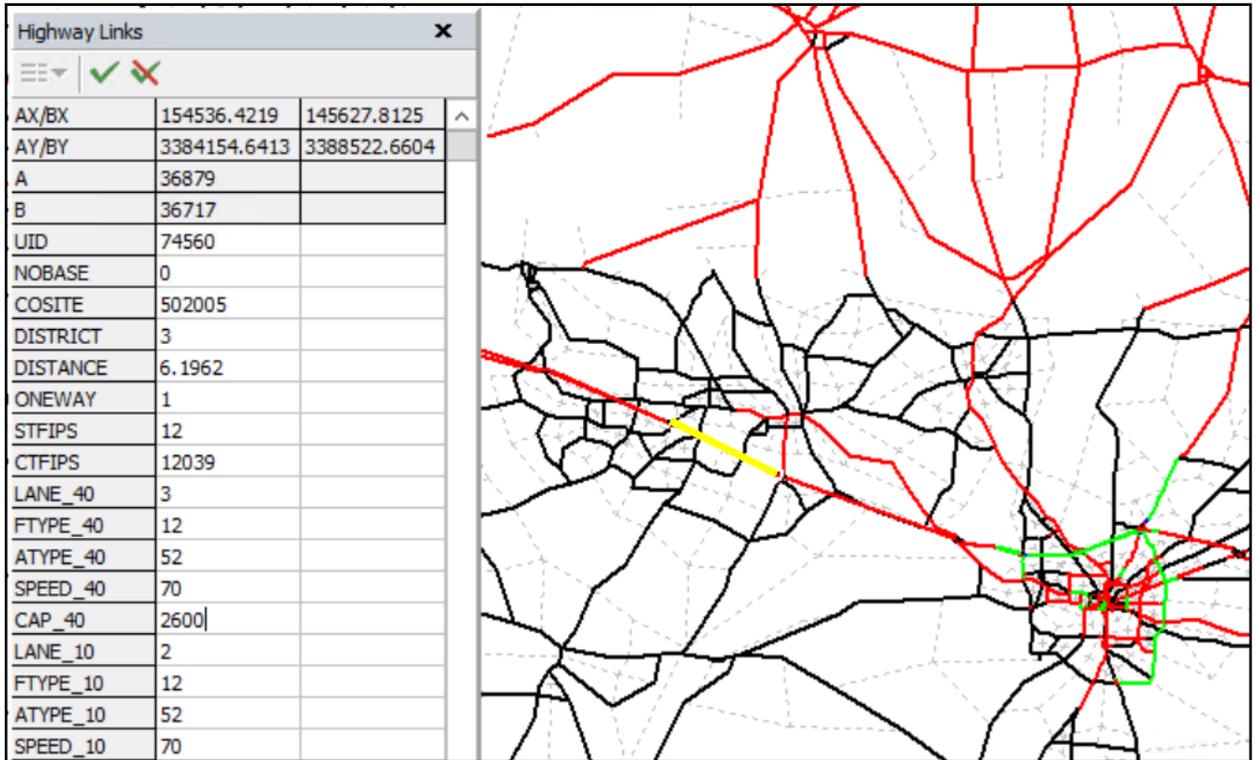


Figure 15 Link 1 modification

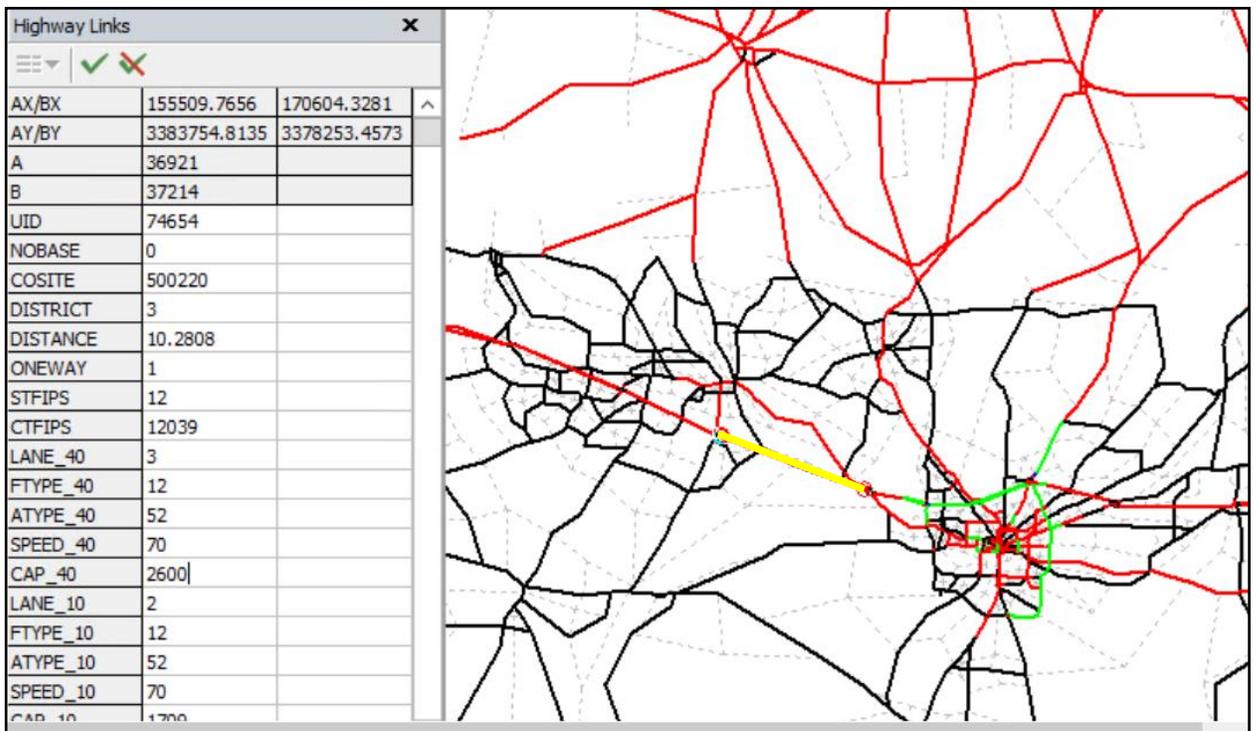


Figure 16 Link 2 modification

5.3.3 Scenario run

Two scenarios were run including the built scenario and no-built scenario in the FreightSIM, of which each run took approximately 12 hours. Below is the information for the FTEIK input:

Study Area

Gadsden

Value of Travel Time

60

Project cost

0

Net Present Value (%)

5

Forecast Years

2040

5.3.4 Truck VHT comparison

FTEIK compares vehicle hours traveled (VHT) for two scenarios including the built and no-built scenario. Below is the chart which shows the VHT comparison for two different scenarios. It could be seen after the run truck driving in the built scenario is less than the no-built scenario, suggesting that the built of highway improves the traffic and reduces congestion.

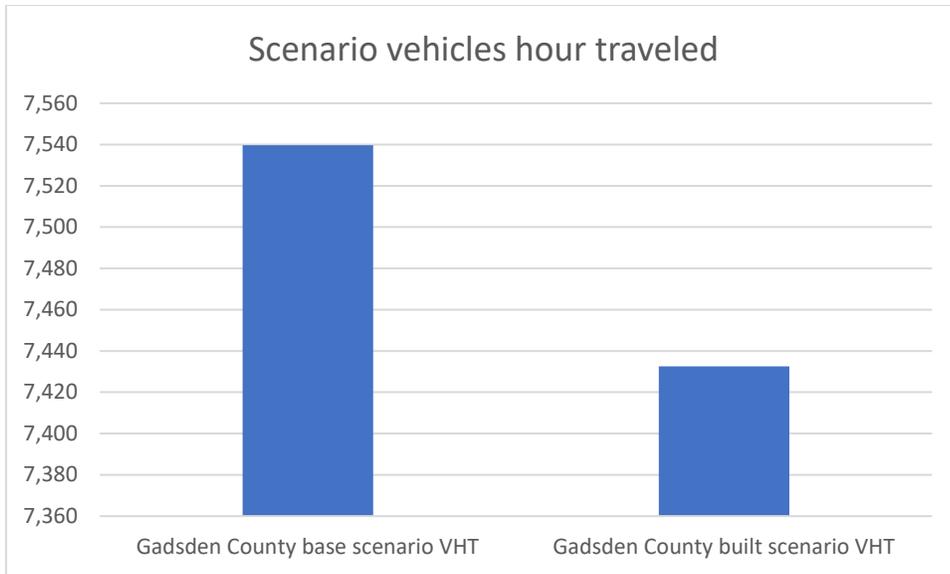


Figure 17 VHT comparison

5.3.5 Results at county level

Table 10 shows the estimated economic impacts by sectors. The total estimated economic impacts will be 5.6 million dollars over 20 years, the income impact will be 1.2 million dollars and the total additional employment will be 51. It could be seen from the table that 48-49 Transportation and Warehousing sector will benefit the most from the highway improvement project. The Real estate and Rental industry will also benefit from the project.

It should be noted that these are only derived based on benefits from the trucking industry. However, the potential economic impacts will be larger than these numbers because the tool does not calculate the travel savings from the passenger transportation and other benefits such as reduced crash, air pollution, etc. This case study only demonstrates the economic impact at county level.

Table 10 Estimated results by sectors

Sector	Sector Output Impact (\$)	Sector Employment Impact	Sector Income Impact (\$)
11 Ag, Forestry, Fish & Hunting	1,100.58	0.00	1,090.09
21 Mining	4,710.83	0.00	1,313.57
22 Utilities	74,417.76	0.00	5,065.89
23 Construction	113,034.94	1.00	26,860.14
31-33 Manufacturing	69,426.90	0.00	15,771.21
42 Wholesale Trade	892,019.36	4.00	245,572.07
44-45 Retail trade	171,637.97	3.00	59,294.78
48-49 Transportation & Warehousing	1,882,970.31	25.00	311,799.31
51 Information	32,146.89	0.00	7,843.52
52 Finance & insurance	536,641.95	3.00	66,949.38
53 Real estate & rental	805,520.49	2.00	19,160.36
54 Professional- scientific & tech svcs	136,891.44	2.00	41,039.21
55 Management of companies	150,787.94	1.00	67,510.19
56 Administrative & waste services	439,795.39	6.00	134,837.98
61 Educational svcs	299.24	0.00	138.92
62 Health & social services	12.86	0.00	5.36
71 Arts- entertainment & recreation	3,705.70	0.00	1,501.41
72 Accommodation & food services	38,954.40	1.00	11,832.17
81 Other services	58,779.07	1.00	28,087.65
92 Government & non NAICs	197,678.53	3.00	162,678.40
Total	5,610,532.55	51.00	1,208,351.62
Net Benefit	0.00	0.00	0.00

5.4 Highway expansion project II

The second case study also derives from the Florida 2040 Strategic Intermodal System (SIS) unfunded needs plan. The project aims to improve interstate highway capacity with additional lanes planned to be built on the Turnpike in the Miami-Dade County. This section will present the use of the kit and results estimates at the state level (county).

5.4.1 Project description

The hypothetical project will be in the Miami-Dade County in the Miami metropolitan area. The project will be adding additional lanes to build 6-lanes on the Turnpike highway, which starts from the Florida State Highway 27 and ends at Florida 823 highway.

5.4.2 FreightSIM modification

The following nodes are located to match the hypothetical project:

3. 71575-72059 (72059-71575)
4. 72104-71572 (71572-72104)

These two links were modified to increase both the capacity and lane numbers in the FreightSIM and the modification is shown in Figures 17 and 18 (Yellow highlighted lines in these two figures show the modified link).

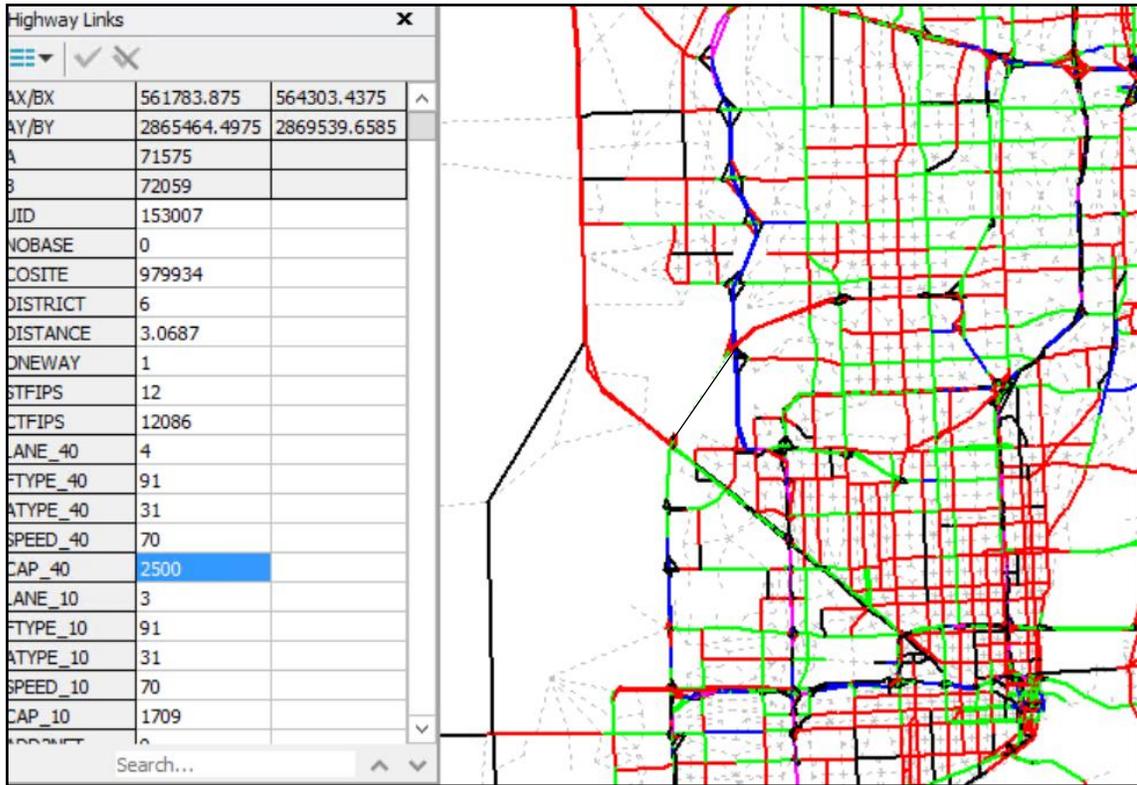


Figure 18 Link 3 modification

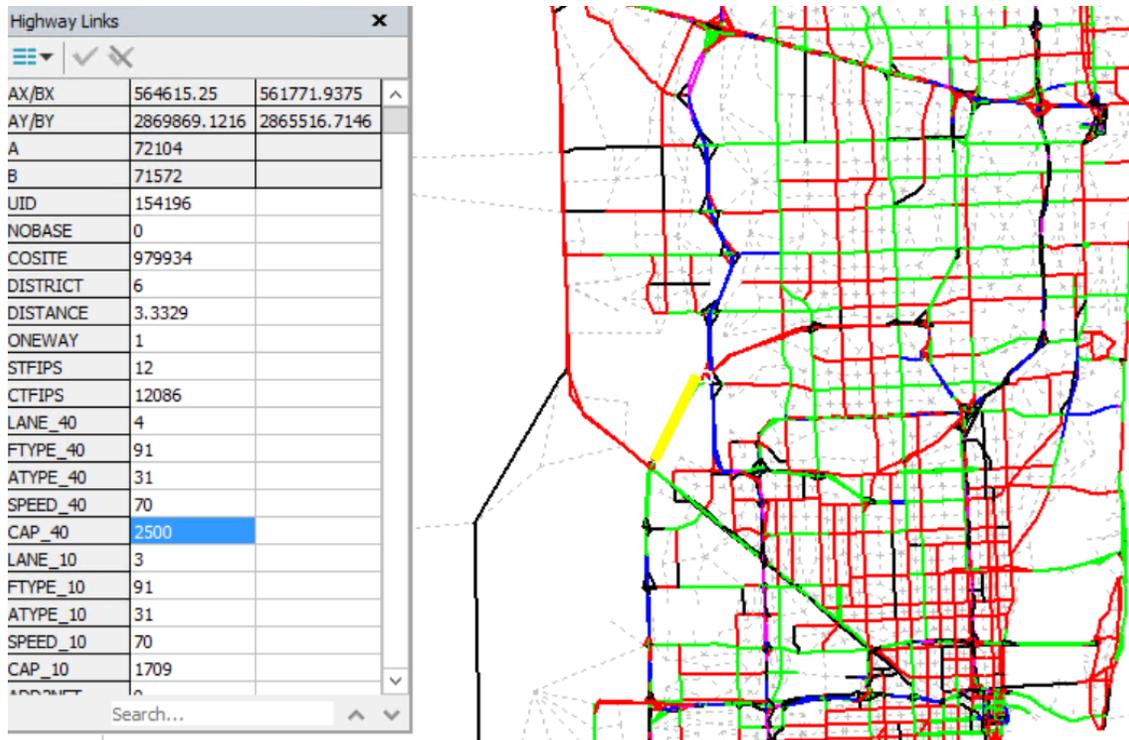


Figure 19 Link 4 modification

5.4.3 Scenario run

Two scenarios were run including the built scenario and no-built scenario in the FreightSIM, of which each run took approximately 10 hours. Below is the information for the FTEIK input:

Study Area

Miami-Dade County

Value of Travel Time

60

Project cost

0 (not available)

Net Present Value (%)

5

Forecast Years

2040

Study Area

Florida statewide

Value of Travel Time

60

Project cost

0 (not available)

Net Present Value (%)

5

Forecast Years

2040

5.4.4 *Truck VHT comparison at state level*

FTEIK compares vehicle hours traveled (VHT) for two scenarios including the built and no-built scenario. Below is the chart which shows the VHT comparison for two different scenarios. The total system VHT for trucks for the built scenario is 3,609,059 compared with 3,613,389 in the no-built scenario². It could be seen in Chart 2 after the run truck driving in the built scenario is less than the no-built scenario, suggesting that the built of highway improves the traffic and reduces congestion in the system at the state level.

² The difference for the system VHT for the state is 4,330. However, the total savings over the study period (25 years) are huge.

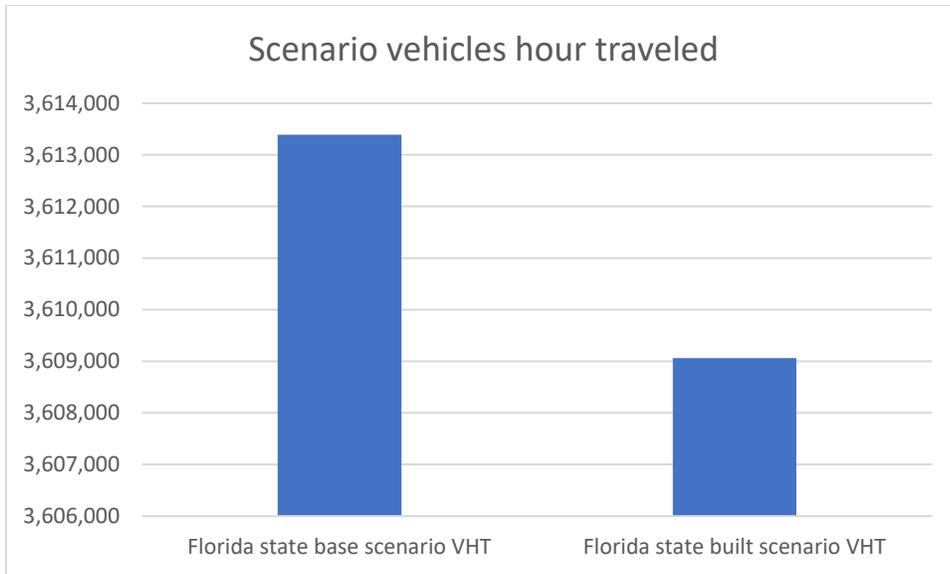


Figure 20 VHT comparison at state level

5.4.5 Results at state level

Table 11 shows the estimated economic impacts by sectors. The total estimated economic impacts will be 355.3 million dollars in terms of industry output over 20 years, the income impact will be 107.6 million dollars and the total additional employment will be 2,068. It could be seen from the table that 48-49 Transportation and Warehousing sector and Finance & Insurance sector will benefit the most from the highway improvement project at the state level.

Table 11 Estimated results at the state level

Sector	Sector Output Impact (\$)	Sector Employment Impact	Sector Income Impact (\$)
11 Ag, Forestry, Fish & Hunting	523,896.06	6.00	185,534.96
21 Mining	512,008.79	3.00	81,910.31
22 Utilities	5,019,315.81	4.00	518,439.66
23 Construction	5,240,302.21	33.00	1,395,312.50
31-33 Manufacturing	21,688,431.29	55.00	3,669,206.46
42 Wholesale Trade	29,196,897.83	116.00	9,537,777.69
44-45 Retail trade	9,007,803.31	112.00	3,689,953.41
48-49 Transportation & Warehousing	100,060,728.66	536.00	31,250,344.16
51 Information	11,711,486.40	27.00	2,342,174.09
52 Finance & insurance	51,736,759.84	257.00	15,143,746.81
53 Real estate & rental	47,404,253.79	164.00	3,265,261.10
54 Professional- scientific & tech svcs	19,983,832.54	143.00	9,650,189.96
55 Management of companies	13,438,508.59	62.00	6,136,388.51
56 Administrative & waste services	23,167,951.12	356.00	11,809,335.97
61 Educational svcs	42,762.15	1.00	25,686.19
62 Health & social services	3,417.89	0.00	1,902.09
71 Arts- entertainment & recreation	966,317.11	11.00	375,174.00
72 Accommodation & food services	3,440,036.10	50.00	1,286,576.91
81 Other services	5,265,126.43	62.00	2,237,747.35
92 Government & non NAICs	6,900,799.64	70.00	4,978,405.86
Total	355,310,635.59	2,068.00	107,581,067.99
Net Benefit	0.00	0.00	0.00

As mentioned in the earlier section, these are only derived based on benefits from the trucking industry due to travel time savings. However, the potential economic impacts will be larger than these numbers because the tool does not calculate the travel savings from the passenger transportation and other benefits such as reduced crash, air pollution, etc. This case study only demonstrates the economic impact at state level.

5.4.6 Truck VHT comparison at the county level

Chart 3 shows the VHT comparison calculated by FTEIK at the county level. The system VHT for the study county also shows a decrease from the no-built scenario to the built scenario.

5.4.7 Estimated results at the county level

FTEIK calculated the estimated economic impact at the county level and the results are shown in Table 12. Similarly, this table provides detail results by economic sectors.

Table 12 Estimated results at the county level

Sector	Sector Output Impact (\$)	Sector Employment Impact	Sector Income Impact (\$)
11 Ag, Forestry, Fish & Hunting	4,225.33	0.00	1,842.67
21 Mining	13,184.66	0.00	3,183.43
22 Utilities	290,999.76	0.00	33,686.59
23 Construction	393,485.70	2.00	103,922.06
31-33 Manufacturing	568,235.33	2.00	84,402.69
42 Wholesale Trade	2,145,217.75	8.00	767,740.36
44-45 Retail trade	726,141.69	9.00	312,852.97
48-49 Transportation & Warehousing	8,306,989.01	32.00	2,023,672.73
51 Information	830,679.66	2.00	188,978.48
52 Finance & insurance	4,391,701.84	20.00	1,499,308.43
53 Real estate & rental	3,728,090.02	15.00	322,814.05
54 Professional- scientific & tech svcs	1,503,142.32	10.00	749,954.04
55 Management of companies	810,961.47	4.00	353,660.31
56 Administrative & waste services	1,506,450.33	26.00	700,104.21
61 Educational svcs	4,388.28	0.00	2,740.26
62 Health & social services	255.26	0.00	138.70
71 Arts- entertainment & recreation	70,053.59	1.00	28,306.77
72 Accommodation & food services	263,655.96	4.00	107,301.61
81 Other services	425,755.75	6.00	173,970.46
92 Government & non NAICs	504,204.07	5.00	364,799.43
Total	26,487,817.79	144.00	7,823,380.27
Net Benefit	0.00	0.00	0.00

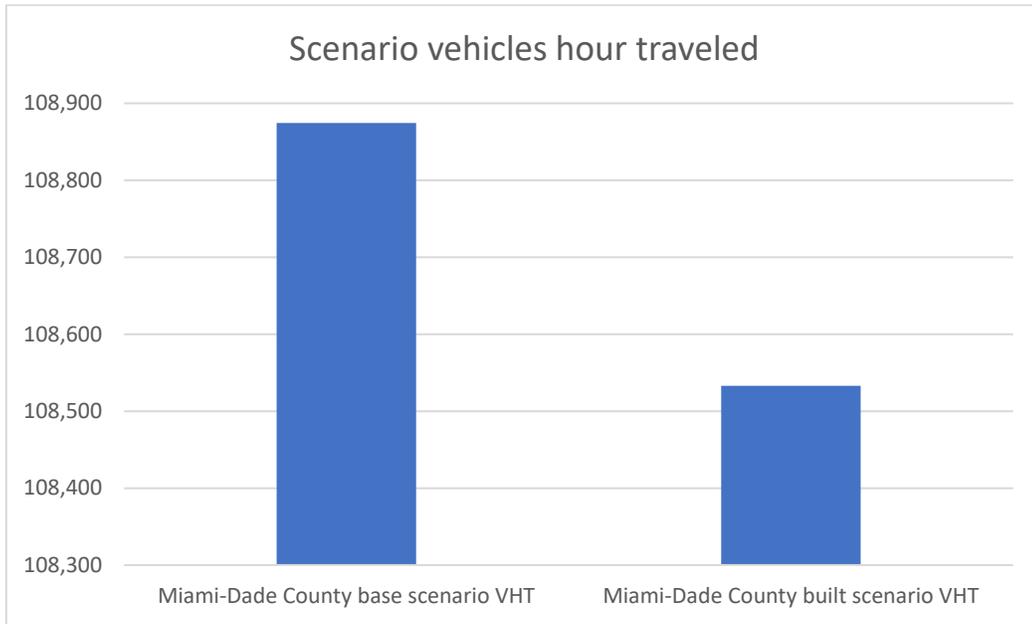


Figure 21 VHT comparison at the county level

5.5 Conclusion

This section presents three case studies at two different levels including the county and state level. FTEIK calculated the output from the FreightSIM run and provided reasonable estimates based on industry input-output relationship. The tool is also able to disaggregate the results by

economic sectors so that policy makers could have an idea in mind which sector will benefit the most from the highway project improvement.

However, caution should be made when interpreting the results, that is, this only calculates economic impacts based on saved trucking travel time. There are other long-term benefits from project such as air pollution, crash, etc. These benefits are beyond the scope of this research.

REFERENCE

- Al-Deek, H., Johnson, G., Mohamed, A., & El-Maghraby, A. (2000). Truck trip generation models for seaports with container and trailer operation. *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 1719, pp. 1-9.
- Aschauer, D. A. (1989). "Is public expenditure productive?" *Journal of Monetary Economics*, 23(2), 177–200. [http://doi.org/10.1016/0304-3932\(89\)90047-0](http://doi.org/10.1016/0304-3932(89)90047-0)
- Bickford, E. (2012). *Emissions and Air Quality Impacts of Freight Transportation*. University of Wisconsin-Madison, University of Wisconsin-Madison.
- Cambridge Systematics Inc. & National Cooperative Highway Research Program (NCHRP). (1997). *A Guidebook for Forecasting Freight Transportation Demand* (No. 388). Transportation Research Board, Washington, D.C.
- Cambridge Systematics, Inc., Marlin Engineering, Inc., & Richard Garcia & Associates, Inc. (2011). *Transportation and Economic Impacts of the Freight Industry in Miami-Dade County*. http://doi.org/http://www.royalcommission.vic.gov.au/finaldocuments/summary/PF/VBRC_Summary_PF.pdf. Cambridge Systematics, Inc., Fort Lauderdale, FL.
- Dablanc, L. (2007). "Goods transport in large European cities: Difficult to organize, difficult to modernize." *Transportation Research Part A: Policy and Practice*, 41(3), 280–285. <https://doi.org/10.1016/j.tra.2006.05.005>
- Danielis, R., Marcucci, E., & Rotaris, L. (2005). "Logistics managers' stated preferences for freight service attributes." *Transportation Research Part E: Logistics and Transportation Review*, 41(3), 201-215.
- De Jong, G., Gunn, H., & Walker, W. (2004). "National and international freight transport models: an overview and ideas for future development". *Transport Reviews*, 24(1), 103-124.
- De Jong, Gerard, & Ben-Akiva, Moshe. (2007) "A micro-simulation model of shipment size and transport chain choice." *Transportation Research Part B: Methodological* 41, no. 9: 950-965.
- Donaldson, D. (2010). *Railroads of the Raj: Estimating the impact of transportation infrastructure* (No. w16487). National Bureau of Economic Research, Cambridge, MA.
- Eberts, R. W. (1990). "Public infrastructure and regional economic development." *Economic Review*, 26, 15–27. [http://doi.org/10.1016/0094-1190\(91\)90053-A](http://doi.org/10.1016/0094-1190(91)90053-A)
- Federal Highway Administration (FHWA) (2015). Measuring the Impacts of Freight Transportation Improvements on the Economy and Competitiveness. Available at: <http://ops.fhwa.dot.gov/publications/fhwahop15034/fhwahop15034.pdf>. U.S. Department of Transportation Federal Highway Administration, Washington, D.C.

- Guzman, A. F., Vassallo, J. M., & Hortelano, A. O. (2016). "A Methodology for Assessing the Regional Economy and Transportation Impact of Introducing Longer and Heavier Vehicles: Application to the Road Network of Spain." *Networks and Spatial Economics*, 16(3), 957–979. <https://doi.org/10.1007/s11067-015-9305-7>
- Herbel, S., Michael D., Meyer, B., & Kleiner, D. G. (2009). A Primer on Safety Performance Measures for the Transportation Planning Process. No. FHWA-HEP-09-043. United States. Federal Highway Administration.
- Holguín-Veras, J., Jaller, M., Destro, L., Ban, X., Lawson, C., & Levinson, H. (2011). "Freight generation, freight trip generation, and perils of using constant trip rates." *Transportation Research Record: Journal of the Transportation Research Board*, (Vol. 2224), pp. 68-81.
- Holguín-Veras, J., López-Genao, Y., & Salam, A. (2002). "Truck-trip generation at container terminals: results from a nationwide survey." *Transportation Research Record: Journal of the Transportation Research Board*, Vol, 1790, pp. 89-96.
- Holland, D.W. & S. Devadoss. "A General Equilibrium Analysis of Foreign and Domestic Demand Shocks Arising from Mad Cow Disease in the United States." *Journal of Agricultural and Resource Economics* 31(2), (2006): 441-453.
- Horváth, E., & Frechtling, D. C. (1999). "Estimating the Multiplier Effects of Tourism Expenditures on a Local Economy through a Regional input-output Model." *Journal of Travel Research*, 37(4), 324–332. <http://doi.org/10.1177/004728759903700402>
- Kockelman, K., Chen, T. D., & Nichols, B. (2013). *The economics of transportation systems: A Reference for Practitioners*. Center for Transportation Research, Austin, TX.
- Konduri, K., Lownes, N., & Angueira, J. (2013). *Analyzing the Economic Impacts of Transportation Projects* (No. CT-2279-F-13-13). Connecticut Academy of Science, Rocky Hill, CT.
- Kreis, D., Howell, B., & O'Connell, L. (2006). *Early Stage Benefit Cost Analysis for Estimating Economic Impacts*. Kentucky Transportation Center, Lexington, KY
- Lakshmanan, T. R. (2011). "The broader economic consequences of transport infrastructure investments." *Journal of Transport Geography*, 19(1), 1-12.
- Lehtonen, M. (2006). "Decoupling freight transport from GDP – conditions for a 'regime shift'." Presented to the 2006 Berlin Conference on the Human Dimensions of Global Environmental Change, Nov. 17-18, 2006, Berlin, Germany. 35 pp. https://userpage.fu-berlin.de/ffu/akumwelt/bc2006/papers/Lehtonen_Decoupling.pdf.
- Lynch, T. (2000). *Analyzing the economic impact of transportation projects using RIMS II, IMPLAN and REMI*. Retrieved from <http://www.cefa.fsu.edu/sites/g/files/imported/storage/original/application/18d780904fc532b3cf0bcdcc8a082bfa.pdf>. Florida State University Institute for Science and Public

Affairs, Tallahassee, FL.

Lynde, A., & Richmond, J. (1993). "Public capital and total factor Productivity." *International Economic Review*, 34(2), 401–414. Retrieved from <http://www.jstor.org/stable/2526921>

Lofgren, H., R.L. Harris, & S. Robinson. (2002). *A Standard Computable General Equilibrium (CGE) Model in GAMS (Microcomputers in Policy Research*, Working Paper No. 5). Washington, D.C.: International Food Policy Research Institute.

Maier, G., Bergman, E. M., & Lehner, P. (2002). "Modelling preferences and stability among transport alternatives." *Transportation Research Part E: Logistics and Transportation Review*, 38(5), 319-334.

McKinnon, A. C. (2007). "Decoupling of road freight transport and economic growth trends in the UK: An exploratory analysis." *Transport Reviews*, 27(1), 37-64.

Meersman, H., & Van de Voorde, E. (2013). "The relationship between economic activity and freight transport." In: Ben-Akiva, M., Meersman, H., Von de Voorde, E. (Eds.), *Freight Transport Modelling*. Bingley, U.K.: Emerald. Pp. 17-44.

Mera, K., 1973. On the urban agglomeration and economic efficiency. *Economic Development and Cultural Change*, 21(2), pp.309-324.

Miller, R. E., & Blair, P. D. (2009). *Input-output analysis: foundations and extensions*. Cambridge University Press, Cambridge, UK

Montolio, D., & Solé- Ollé, A. (2009). "Road investment and regional productivity growth: the effects of vehicle intensity and congestion." *Papers in Regional Science*, 88(1), 99-118.

Munnell, A. H. (1990). Why has productivity growth declined? Productivity and Public Investment. *New England Economic Review*, (Jan./Feb.), pp. 3–22. Retrieved from <http://ideas.repec.org/a/fip/fedbne/y1990ijanp3-22.html>

Nadiri, I. M., & Mamuneas, T. P. (1998). Contribution of highway capital to output and productivity growth in the US economy and industries. Federal Highway Administration, Washington, DC.

National Cooperative Highway Research Program (NCHRP). (2017). *Guidebook for Freight Policy, Planning and Programming in Small- and Medium-Sized Metropolitan Areas*. NCHRP Report 570. Washington, D.C.

Pastowski, A. (1997). *Decoupling economic development and freight for reducing its negative impacts* (No. 79). Wuppertal Institute for Climate, Environment and Energy, Wuppertal, Germany.

Pradhan, R. P. (2010). "Transport infrastructure, energy consumption and economic growth triangle in India: cointegration and causality analysis." *Journal of Sustainable Development*, 3(2), 167.

- Rickman, D. S., & Schwer, R. K. (1995). "A comparison of the multipliers of IMPLAN, REMI, and RIMS II: Benchmarking ready-made models for comparison." *The Annals of Regional Science*, 29(4), 363–374. article. <http://doi.org/10.1007/BF01581882>
- Sahoo, P., & Dash, R. K. (2010). "Economic growth in South Asia: Role of infrastructure." *The Journal of International Trade & Economic Development*, 21(2), 217–252. <http://doi.org/10.1080/09638191003596994>
- Seabrooke, W., Hui, E. C., Lam, W. H., & Wong, G. K. (2003). "Forecasting cargo growth and regional role of the port of Hong Kong." *Cities*, 20(1), 51-64.
- Seetharaman, A., Kawamura, K., & Bhatta, S. (2003). "Economic benefits of freight policy relating to trucking industry: Evaluation of Regional Transportation Plan freight policy for a six- county region, Chicago, Illinois." *Transportation Research Record: Journal of the Transportation Research Board*, (Vol. 1833), pp. 17–23.
- Seethepalli, K., Bramati, M. C., & Veredas, D. (2008). How relevant is infrastructure to growth in East Asia? No. 4589. World Bank, Washington, DC.
- Shin, H.-S., Bapna, S., Farkas, A., & Bonaparte, I. (2015). State highway administration measuring the economic contribution of the freight. State Highway Administration, Baltimore, MD,
- Taylor, C. (1993). Micro IMPLAN User's Guide. Washington, D.C.: Land Management Planning Systems Group, U.S Forest Service.
- Vilain, P., Muhammad, T., Li, C., & Hallissey, M. (2010). "Freight and passenger modeling using hybrid econometric-network models." *Transportation Research Record: Journal of the Transportation Research Board*, (2187), 97-105.
- Voigtlaender, N. (2002). *A Dynamic input-output Model to Project U.S. Freight Transportation Demand* (master's thesis). Cambridge, MA: Massachusetts Institute of Technology.
- Wang, Z., Sage, J., Goodchild, A., Jessup, E., Casavant, K., & Knutson, R. L. (2013). "A Framework for Determining Highway Truck-Freight Benefits and Economic Impacts." *Journal of the Transportation Research Forum* (Vol. 52, No. 2, pp. 27-43).
- Weisbrod, G., & Weisbrod, B. (1997). *Measuring economic impacts of projects and programs*. Economic Development Research Group, Boston, MA.
- Wing, Ian Sue. (2004), "Computable general equilibrium models and their use in economy-wide policy analysis." Technical Note, Joint Program on the Science and Policy of Global Change, MIT, Boston, MA.
- Woo, S. H., Pettit, S. J., Kwak, D. W., & Beresford, A. K. (2011). "Seaport research: A structured literature review on methodological issues since the 1980s." *Transportation Research Part A: Policy and Practice*, 45(7), 667-685.

Wygonik, E., Holder, D., McMullen, B., & Goodchild, A. (2014). “Current State of Estimation of Multimodal Freight Project Impacts.” *Transportation Research Record: Journal of the Transportation Research Board*, Vol. 2410, pp. 141–149. <https://doi.org/10.3141/2410-1>

Yu, H. (2017). “A review of input–output models on multisectoral modelling of transportation–economic linkages.” *Transport Reviews*, Online publication first, 1-24. <https://doi.org/10.1080/01441647.2017.1406557>